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CLINICAL REVIEW

CASE REPORT

The Journal of the World Federation of Societies of Anaesthesiologists

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Editorial

This edition of the UIA has been 2 years in the making, and I thank all the contributors for their incredible patience and fortitude. We had hoped to publish it much earlier, and sincerely apologise to all our authors for not getting through the editorial process sooner. A big thank you to Prof Ronke Desalu from the Dept. of Anaesthesiology, University of Lagos in Nigeria, for her unwavering support and assistance with the editorial process. When it comes to Paediatric Anaesthesia, I feel somewhat out of my comfort zone.

I am very excited at having contributions from high, middle and low-income countries, and in particular, so many contributions from colleagues in Africa, illustrating that practicing anaesthesiology in some remote areas of my continent is not for the faint hearted. We sadly see extreme pathology that our colleagues practicing in the first world environment only read about in journals and text books.

This is our last printed copy of the UIA, owing to financial constraints. We will continue to publish our editor's contributions on line, some as individual stand-alone articles, and some in themed "Edition" contributions. We already have a few articles in the wings, awaiting the editorial process. My sincere and warm thanks to Kristine, Amal and Francis for their amazing support from the WFSA office.

We welcome your contributions to the journal, and if you have any suggestions about the journal or manuscripts that you would like to be published, please do not hesitate to get in touch. You can find contributor guidelines and submit manuscripts directly through our online submission system at:

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Once again, a huge thank you to all our contributors and reviewers.

Christina Lundgren

Co-Editor-in-Chief
Update in Anaesthesia

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Paediatric critical care in resource-limited settings: An overview

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Abstract

Paediatric critical care in lower resource settings can often become the responsibility of the anaesthetist, whether there has been formal training in paediatric care or not. Here we aim to provide an overview of the current state of pediatric critical care in resource-limited settings: the burden of illness and need, staffing, outcomes, and capacity. Barriers to the provision of consistent quality care are reviewed, as are ethical considerations at the level of the institution and the patient.

Key words: pediatric intensive care units; pediatrics; resource allocation; resource-limited settings

INTRODUCTION

The provision of paediatric critical care in low- and middle-income countries (LMIC) presents unique challenges for physicians and nurses. The increasingly frequent acquisition by hospitals of equipment such as mechanical ventilators, drugs which can provide vasoactive support, and the expanding capacity to provide emergency surgical care have all translated into a need for thoughtful deployment of existing personnel and resources. Here we touch on some of the relevant issues in the current practice of pediatric critical care in LMIC.

Burden of Critical Illness

Several web-based databases such as World Health Organization's Global Health Observatory report the burden of discrete diseases such as malaria, HIV and meningitis. Literature on the incidence and prevalence of critical illness syndromes, such as multiorgan failure, acute kidney injury, and sepsis, are difficult to find because no single test exists to diagnose them; they rely on multiple tests that include both radiological, laboratory, clinical and physiological criteria agreed upon by experts who are constantly debating and revising the criteria. While these might be readily available in resource-rich countries, the majority of low and middle-income countries will not have the necessary resources to diagnose these syndromes during critical illness, document it effectively, and carry out research. Even the SPROUT study, which aimed to assess the global point prevalence of paediatric severe sepsis worldwide, garnered the majority of its data from high-income countries (HIC), with only three hospitals from Africa (all from South Africa) reporting.[1]

The true burden of paediatric critical illness therefore remains unclear and this hinders both local and global appreciation.

However, the under-five mortality rate in many LMIC remains markedly higher than that in most HIC. It is known that the majority of childhood deaths result from preventable and reversible illnesses like meningitis, malaria and tuberculosis and complications from birth asphyxia in the neonatal period. All of these present with a period of critical illness during their disease progression.[2] By extrapolation, the burden of critical illness - even though debated - is clearly significant.

PICU Staffing in LMIC

While many children receiving critical care in LMIC are cared for in mixed adult/paediatric units, even when designated PICUs are in place, significant staffing challenges exist. There is a marked lack of paediatricians trained in critical care in most LMIC, and consequently the care of critically ill children is often assumed by some combination of general paediatricians, adult anaesthetists, trainees/registrars, and/or general practitioners, particularly in smaller district hospitals.[3-5] It is not uncommon for physicians to work in shifts with duties split between multiple hospitals in order to maintain their income. Subspecialized allied professionals such as respiratory therapists, dieticians, pharmacists, and physical therapists are generally lacking. Nursing staff may not have critical care training, but rather be assigned to ICU by virtue of having more clinical experience or increased seniority compared to other staff.

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These practices, in our experience, are complicated by a dearth of published information regarding staffing of critical care units in resource-limited settings. A systematic review of ICU capacity in low-income countries (based on World Bank definition) in 2015 revealed that the majority of LIC had no literature on ICU capacity; of the remaining countries for whom data existed, only one reported physician staffing while two reported nursing ratios.[3]

PICU Outcomes

A paediatric intensive care unit is a designated space/facility that is specifically designed to admit children who because of life threatening conditions, severity of illness, or post-surgical state require continuous care by the nursing and physician teams with or without ICU-specific supports such as mechanical ventilation or vasoactive infusions. The goal of the PICU staff is to support the body during the transition time of physiological deficiencies while the underlying cause is treated or resolves. PICU admission is determined by the admission criteria that is generally unique to specific centers but is designed to maximize benefit to both the patients and hospitals that they serve.

Different metrics in the assessment of ICU outcomes exist; one can assess mortality or morbidity of targeted populations such as patients with septic shock, traumatic brain injury or acute respiratory distress. Mortality or morbidity can be measured at different timelines such as at 6 months, 1 year or even prolong it further to assess quality of life at 10 years post-discharge from the ICU.

The world all over is moving away from simply looking at mortality after ICU admission. Instead research is now focusing on the ability to live a normal or close to normal childhood and the ability to integrate into society of both the child and their caregivers.

While there are no agreed guidelines on assessment of outcomes in critically ill children and no registries for children that have gone through the existing intensive care units in LMICs, reported mortality rates in literature from the available PICUs range from 2.1% in India[6] to as high as 42% in some sub-Saharan African countries.[7] These figures, when compared to those coming from high-income countries (8-18%), are a reflection of the room for growth in this young field of medicine.

ICU Resources and Capacity

The definition of an ICU bed and therefore an ICU varies around the world and is largely shaped by economic factors, hospital priorities, and public health regulatory requirements and priorities. Factors that generally delineate an ICU from a ward include physical space, support and monitoring technology, human resources to provide intensive nursing care, critical services provided that are beyond the immediate demands of the individual patients such as rehabilitation, and the ability to carry out research, education and quality improvement.[8] A survey done in 2016 from 34 low and middle income countries found that the number of paediatric intensive care unit (PICU) beds is comparable to high income countries[3] while some research respondents in other studies say that they do not have designated space to call a PICU but rather paediatric critical care is carried out in a mixed adult/paediatric ICU.[9] Even when available, the average number of PICU beds can be quite small; in a study from Pakistan, the rate ranged from 0.5-1 per 100,000 children[10].

Barriers to Quality Care

Barriers to the implementation of high-quality critical care in LMIC are significant. Care for life-threatening conditions in resource-limited settings is often limited to basic health care resources and thus presents a challenge to implementation, development and sustainability of critical care services. Even while some private hospitals in urban centers are able to offer ICU services on par with those found in high-income countries, resources at these facilities can stand in stark contrast to the typical resources available at district hospitals in the same country, or even public hospitals in the same city.[5] Illustratively, a survey of anaesthetists and ICU physicians in 2011 concluded that the most recent Surviving Sepsis guidelines cannot be implemented in Africa, particularly sub-Saharan Africa due to the shortage of required hospital facilities and equipment.[11] Impediments to the provision of critical care are various: challenges in personnel, equipment, and health care systems all contribute to suboptimal care and paediatric mortality.

With respect to the existence of appropriately trained personnel, few formal training programs for physicians or mid-level providers in paediatric critical care exist outside of high-resource settings.[12] The so-called "brain drain" has led to emigration of physicians from LMIC to higher-income countries that are made attractive by training opportunities, better income, and increased resources. Programs such as the African Paediatric Fellowship Program, which since 2008 has offered focused training for six months to two years in paediatric subspecialties for physicians committed to returning to their home country, aim to increase local capacity in countries where specialists are either few or nonexistent.[13] PECC-Kenya launched in January 2019 as the first combined paediatric emergency and critical care fellowship program in Africa[12]; the Ecuadorian Laude program in PCCEM has innovatively utilized interprofessional education since 2013 to train providers who are already caring for critically ill children.[4] These initiatives are encouraging, but it will be some years before the workforce will increase dramatically. Until then, critically ill children will continue to receive care from physicians and providers without specialized PICU training. Online resources such as OPENPediatrics[14] can be effective stopgaps, but the need to increase the resources for training is clear.

Similar to the barriers physicians face when seeking specialized training in critical care, opportunities for training in critical care nursing in LMIC are often scarce. These programs, when available, often remove experienced nurses from their home institutions, leaving a gap in nursing leadership for the duration of their training. And just as promising young physicians often emigrate from their home countries, trained nursing staff can be subsequently lost to higher paying jobs in more desirable locations after they have gained these new and valuable skills.

Even when adequately-trained personnel are present, necessary supplies and equipment – for example, reliable electricity, functioning ventilators, oxygen supply, timely laboratory support, or monitors – may not be. Children seen and evaluated in the community may have to travel some distance to access critical care resources; availability of transportation, cost, and late presentation can all compromise the ability to receive life-saving care, even when available. Finally, the triage of patients in centers where need for critical care far outstrips

the capacity of the institution can suffer from the frequent practice of caring for the very sickest patients in the ICU. The Society for Critical Care Medicine guidelines for adult ICU admission suggest "ICU admission criteria should select patients who are likely to benefit from ICU care"[15], but that determination in resource-limited settings can be fraught with challenges. Identification of reversible illness – and distinguishing that from illness which might have been reversible three days ago but is no longer – is not straightforward, even in previously healthy children.

Ethics Surrounding Provision of PICU Care in LMIC

Critical care is a resource-intensive undertaking, and the arguments surrounding the pro and con views on its provision in resource-limited settings are ongoing. The main relevant ethical principle is that of justice: while a more global view of justice affirms that all children ought to be able to access the same types and quality of medical care[5], the practical aspects of resource allocation render that goal currently unachievable. In addition, some argue that the high cost of critical care for a few children is inappropriate in the setting of ongoing mortality from disease in which lower-cost community-health level interventions (e.g. vaccination programs) have the potential for a larger impact in mortality rates. However, as progress has been made toward the WHO's Millennium Development Goal #4 (reduction of the under-5 mortality rate), the relative merit of higher-cost, resource-intensive care has increased.

In LMIC, resources are often either unavailable or limited in quantity and are simply inaccessible to children who might benefit from them. Their provision may, in some situations, devastate the finances of the family whose child receives them.[5] In circumstances in which they are available, therefore, transparency and consistency surrounding these difficult life-and-death decisions are essential to the development of a robust critical care service. As an example, in South Africa, the Red Cross War Memorial PICU team has created explicit triage criteria to assist in selecting children appropriate for admission to their PICU.[16] Their process delineated specific populations who would be excluded from PICU admission based on futility of care or likely poor prognosis, reducing pressure on PICU staff by outlining clear expectations in advance. Frameworks such as this can help identify children who are most likely to benefit from ICU care with return to a baseline state of health.

Aside from the ethics of resource allocation, a nuanced approach to local beliefs and customs is necessary in the provision of critical care to children. For example, in higher-resource settings, it is generally accepted that withdrawal of intensive supports is ethically equivalent to withholding them. However, in many LMIC it is culturally or religiously inappropriate to consider withdrawal of life-sustaining therapies, even in the face of an extremely poor prognosis or inevitable cardiopulmonary death. Similarly, while the concept of brain death is widely accepted in the medical literature, understanding in the lay public in resource-limited settings is lacking. Compounding the lack of public knowledge is a lack of protocol for its declaration: brain death protocols did not exist in the majority of LMIC in a 2015 survey.[17] A retrospective chart review in a Malawi ICU identified patients with neurologic signs concerning for brain death; all 43 patients were declared dead after cardiac death.[18] Lack of consensus around the concept of brain death can lead to misuse of precious ICU resources for patients in whom ongoing supportive care is futile.

In short, accessibility of critical care resources, criteria for their provision, and cultural context are all ethically essential considerations in the establishment and ongoing administration of paediatric critical care.

CONCLUSIONS

The argument for an increase in the capacity to care for critically ill children in resource-limited settings is compelling as we find ourselves in a season of shifting priorities and health care system investments. It is clear that thoughtfulness and intentionality are necessary as decisions are rendered by individual institutions around the type of care provided, how to allocate resources, and how to identify skilled providers. With the burgeoning interest in paediatric critical care, we anticipate that the coming years will provide ample opportunity to rigorously build a body of knowledge around best practices and, ultimately, improve the quality of care children receive in resource-limited settings.

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Update in
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Paediatric burn injury: key points for the anaesthesiologist

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Abstract

Burns are the eleventh leading cause of deaths in childhood and the fifth most common cause of non-fatal childhood injury, and most often occur in children under 4. 80% to 90% of all severe burns occur in low to middle income countries. Anaesthesiologists are crucial members of the multi-disciplinary team caring for children with burns. Provision of adequate analgesia, sedation, anesthesia and intensive care treatment are roles of anaesthesiologists and non-physician anaesthetists. There are several anaesthetic challenges with managing the child with burns such as a potential difficult airway, challenging intravascular line placement, water and electrolyte disturbances, altered temperature regulation, sepsis, cardiovascular and respiratory insufficiency, altered pharmacokinetic and pharmacodynamics pathways. The majority of critical adverse events in burn injured patients are associated with the airway and hemodynamic instability. The specific anaesthetic technique required depends on the individual patient pathophysiology condition. With the progress in burn care trauma protocols and with the development of multidisciplinary teams at special burn units, outcomes have improved over the past two decades. This review provides insights into existing therapeutic approaches for the management of paediatric burns.

Key words: anaesthesia, intensive care, paediatric, burn injury

INTRODUCTION

Burns are the eleventh leading cause of deaths in childhood and the fifth most common cause of non-fatal childhood injury[1]. Children under 4 years are at highest risk of burn injuries, almost double that of all other pediatric age groups[2]. Even though the global mortality rate associated with burn injury has decreased in past two decades, burns remain a significant source of morbidity and mortality in childhood[3, 4].

It is crucial to understand how a child is different from an adult in size, body surface area, temperature regulation, skin thickness and metabolic rate[5,6]. The younger the child, the greater the mortality because of deeper burns due to thinner skin, more complexity of fluid resuscitation, smaller upper airways, difficult vascular access and immature immune system[7].The initial management is very important and should focus on the ABCDE algorithm[8].

Improved outcomes in past decades can be attributed to advances in resuscitation, protocols for intensive care, improved coverage of wounds and treatment of infections, better treatments for inhalation injury and for hypermetabolic response[9]. Severe paediatric burns may require long-term rehabilitation treatment and may be associated with psychosocial consequences. The goals of burn care are to preserve life and function, to limit physical and psychological sequelae and to provide social reintegration[10].

CLASSIFICATION AND SCORING SYSTEMS

Burns may be caused by heat, chemicals, electricity, or radiation. The severity of burn injury can be characterized by the depth of the burn, the total body surface area (TBSA) of the burn, the location of burn injury and the presence of inhalation injury[11]. Burns are classified according to of the burns into three main categories: first, second and third degree. First-degree burns are superficial and only affect the epidermis, where the skin is red and painful. These rarely require hospital treatment. Second-degree burns affect both the dermis and epidermis, and the skin may be swollen, red or white, have blisters and be very painful. Third-degree burns are the most severe and reach through the skin layer to the hypodermis. Nerves may be destroyed causing severe pain or numbness. Skin may look charred, raised, leathery and blistered.

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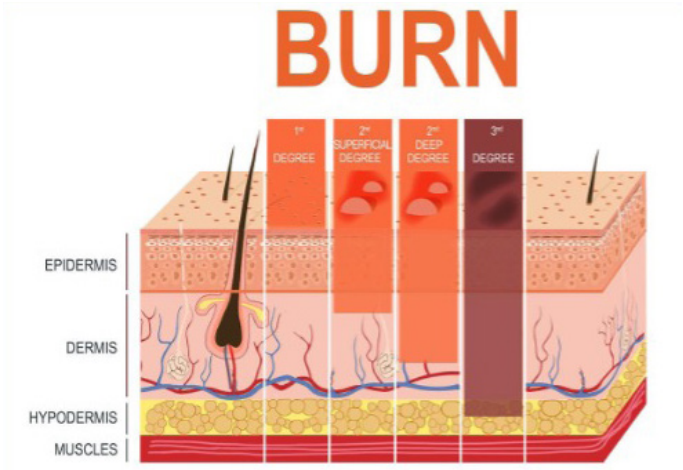

Figure 1. The skin structures affected by different degrees of burn. (Taken from Swiss Med Wkly. 2019;149:w20079) licensed under CC BY-NC-ND

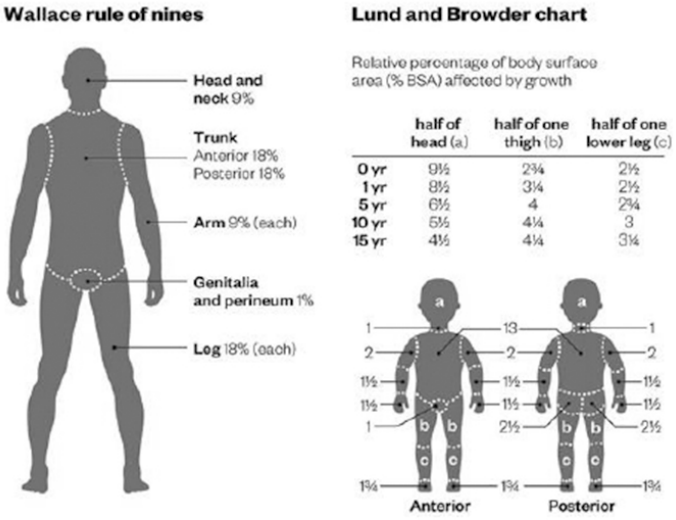

Figure 2. Body surface area estimation: Rule of nines and Lund and Browder chart.

To estimate the total body surface area (TBSA) burns in children, Lund and Browder charts may be used, which takes into account changes in the body proportions of growing children. In children, the head and neck occupy a larger, and the lower extremities occupy a smaller, proportion of the total body area. The rule of nine is useful for estimating burns in children older than 14 years. The area of the child's palm corresponds to approximately 1% of the total body surface area and this simple method can be useful when Lund and Browder charts are not available or when the burns are irregular in shape and non-confluent[12] (Figure 2).

Burns that affect more than 10% TBSA, or more than 5% TBSA of deep burns are considered to be serious as they are life-threatening. In neonates, a smaller TBSA causes more severe burn injury than in older children, due to the immaturity of the organ systems and the subsequent difficulty in maintaining homeostasis[13].

For estimating the severity of burns are used two scoring systems: the Paediatric Risk of Mortality (PRISM) score and the Abbreviated Burn Severity Index (ABSI)[14]. The PRISM scoring system utilizes 14 variables including vital signs and lab values, which are collected over the first 24 hours after admission to hospital. The ABSI score is calculated from five variables (sex, age in years, inhalation injury, full thickness burn, total body surface area burned) that can be rapidly assessed at the time of admission, which eases calculation and allows for immediate prediction of mortality. Both PRISM and ABSI scores predict mortality in children with severe burns, whether analysed alone or in a combined model. These scoring systems have advantages and disadvantages, so further validation of these scores need to be done with prospective studies. A detailed summary of these scoring systems is beyond the scope of this article.

PATHOPHYSIOLOGY

The skin serves as a barrier to protect the body from infection and to prevent heat and fluid losses. Therefore, destruction of this barrier by a burn injury can lead to infection and to altered heat and fluid regulation[9].

Severe burn injury also induces the release of local and systemic mediators of inflammation. Local mediators, which include prostaglandins, leukotrienes, bradykinin, nitric oxide, histamine and oxygen free radicals, cause localized and systemic capillary leak with resultant oedema. Systemic mediators like interleukins and tumour necrosis factor alpha (TNF-α) cause a systemic inflammatory response that occurs almost immediately post injury. This liberation of pro-inflammatory mediators leads to the release of stress hormones that cause a hyper-metabolic state 3–5 days after the burn injury. Pathophysiologic changes occur in every organ systems and they can be divided into two phases: the acute phase, which resolves within 24–48h and the late or hypermetabolic phase[15].

Table 1: Classification of burns according to severity

Minor	Moderate	Severe
< 5% of body surface area	5-10% body surface area	> 10% of body surface area
< 2% deep burns	2-5% deep burns	> 5% deep burns
	Suspected inhalational injury	Electric burns (electrocution)
	Circumferential burns	Inhalational injury
	Comorbidity (diabetes, etc.)	Burns of the face, hands, feet, perineum
		Significant associated trauma

INTRAHOSPITAL STRATEGIES IN TREATMENT

Early recognition and management of life-threatening injuries can have a significant impact on outcomes in burns. The mechanism of burns is extremely important, and if it occurred as a result of an explosion, traffic trauma or suspected joint injury, the priority is the evaluation of trauma. The primary and secondary examinations are done following Advanced Trauma Life Support standards[16]. After the primary assessment, a burn-specific secondary examination should be done in a way of estimation for the possibility of inhalation injury, intoxication with carbon monoxide and cyanide and accurate assessment of the burn wounds.

The management of burns can be considered in three phases. The first phase includes prehospital care and the early hospital phase: adequate and prompt first aid, assessment of the burns, resuscitation, escharotomies or fasciotomies and the management of inhalation injury. The second is the late hospital phase: wound care including burn surgeries, infection control management, maintainance of organ function and attenuation of hypermetabolism. The third phase is the long-term phase: management of persistent hypermetabolism, reconstruction and rehabilitation[9].

AIRWAY MANAGEMENT: WHEN TO INTUBATE?

The airway of children is much smaller in diameter than adults and is very quickly endangered by oedema, so early intubation is advised if required. Intubation should never be postponed for more than a few hours in the case of cervicofacial burns, because the progressive oedema accelerates between the 4th and 8th hours to reach a maximum between the 12th and 36th hour post-burn[17]. Progressive unrecognized oedema can make intubation difficult and multiple failed attempts can worsen oedema in an already tight airway.

A high degree of suspicion for inhalation injury is essential. If the burn is a consequence of a fire, especially indoors, there is a possibility of inhalation injury to the respiratory tract.

Inhalation injury leads to oedema of the upper respiratory tract and chemical irritation of the lower respiratory tract. Clinical signs for inhalation injury are respiratory distress, hypoxemia, stridor, wheezing, oropharyngeal blistering, tongue swelling, carbonaceous sputum and singed eyebrows and nasal hairs. If there is any doubt about airway patency or the possibility for airway deterioration, the decision should be made for prompt endotracheal intubation. These patients should not be prophylactically intubated, neither to get prophylactic antibiotic therapy. Standard protocols for inhalation injury include bronchodilators, nebulised heparin, nebulised acetylcysteine and for extreme oedema, racemic adrenaline[18].

The underlying mechanism in acute lung injury is impairment of alveolar membrane function, which often becames apparent 24 to 48 hours after the initial burn injury. The treatment is similar to adult respiratory distress syndrome and is associated with increased morbidity and mortality[19].

VASCULAR ACCESS

Venous access should be obtained as soon as possible, through intact skin if possible. A venous line may be placed through burned skin if unavoidable, but securing the cannula may be difficult. Placing an intravenous line distal to a circumferential burn injury must be avoided because the constrictive effect that may develop can reduce venous return from distal parts of a limb. Two large peripheral venous lines are usually sufficient. In the case of failure to place a peripheral line, central venous access may be required and an intra-osseous needle may be required for resuscitation, but should be replaced within 24 hours[20,21].

FLUID RESUSCITATION: CRYSTALLOIDS AND COLLOIDS

Many formulas for fluid resuscitation in burns patients have been studied and all have the same goal: keeping sufficient organ perfusion. All formulas tend to fulfil two main rules: a) the minimum amount of fluid needed to maintain sufficient organ perfusion should be infused, and b) the volume needs to be carefully titrated to avoid under- and over-resuscitation. Optimal fluid resuscitation remains a matter of debate, with studies addressing not only the amount of fluid used in resuscitation, but also the type of fluid. No large prospective randomised trials have been done to establish whether crystalloids are better than colloids in resuscitation.

For initial fluid resuscitation in children with burns, crystalloids are the first choice during the initial 24 hours post-burn period[20]. The Parkland Formula is most commonly used[22,23].

Total volume of crystalloid to be given in the first 24h = 4ml/kg body weight x % TBSA burned

However, recent data[19] suggest the Parkland Formula may underestimate the fluid requirements in children younger than 3 years, patients with severe large and deep burns, those with associated inhalation injury, alcohol or drug use and electrical injury. Fluid balance can be challenging with under-resuscitation leading to multiple organ failure (MOF) and increased mortality. Over-resuscitationmay lead to worsening of oedema, deteriorating gas exchange, pleural effusion, pericardial effusion, pulmonary oedema, acute respiratory distress syndrome, compartment syndrome, central neurological ischemia and multiple organ failure.

Oral hydration is most appropriate for burns with less than 10% TBSA in infants and children and with less than 15% TBSA for older children, if the injury does not interfere with a child's ability to take fluids by mouth. Enteral nutrition demands need to be carefully supervised due to gastric paresis and food aversion can disturb a child's ability to keep sufficient hydration and nutrition.

The optimal time to safely start using colloids is the subject of much debate. The time at which the protein leakage stops has been described differently in the literature. Capillary integrity is thought to have recovered 12 to 24 hours after the burn, and this is one of the strategies when to start using colloids. In the opinion of Cocks et al[25] albumin extravasation stops 8 h after burn injury. As claimed by Demling[26], capillary leakage of protein reduces remarkably about 12h after burn injury.

5% Albumin solutions may be started after 24hours in a stable patient or 8 hours post-burn in a patient with difficult resuscitation at a dose of 0.75^{-1}g/kg/day in order to keep an albumin concentration >2.0g/dl. Serum albumin concentration should be monitored every 12 hours[20,27].

Acute changes in serum sodium levels can promote seizures, cerebral oedema and central pontine myelinolysis—each one is related to higher mortality risk[28].

One of the biggest challenges in fluid resuscitation is monitoring whether the infused volume is adequate. Formulas only ensure assessments of fluid demands, but reestablishment of intravascular volume must be controlled by indirect clinical signs such as capillary refill, heart rate, blood pressure and urine output. The satisfactory hourly urine output is the gold parameter for adequate fluid resuscitation, for children less than 30kg the goal is a urine output of 1ml/kg/h, and for children over 30kg the goal is urine output 0.5ml/kg/h[29]. Hemodynamic targets are: systolic blood pressure values for children <1 month of age: 60mmHg, from 1 month to 10 years: 70+ (2 x years), and for older than 10 years: 90mmHg; mean arterial pressure (MAP)> 65mmHg. Global perfusion indicators (lactates, baseline deficit, central venous blood saturation) are more reliable than diuresis and correlate with burn rate and mortality[29].

ANALGESIA AND SEDATION OUTSIDE THE OPERATING ROOM

Analgesia should always be multimodal and multidisciplinary and include non-pharmacological and pharmacological methods with non-opioid and opioid analgesics. The pain burned patients experience may be divided into a 'background' pain and a 'breakthrough' pain associated with painful procedures. While background pain may be controlled with intravenous opioids via continuous infusion or patient or nurse-controlled analgesia (PCA/NCA) and/or less potent oral opioids, breakthrough pain may be treated with a variety of interventions[30]. The intramuscular, subcutaneous and oral routes should be avoided because of unreliable systemic absorption associated with the shock state and delayed gastric emptying. In order to reduce the use of high opioid doses, other agents can be used as analgesic adjuncts, such as acetaminophen, ketamine, or an alpha-2 agonist, such as clonidine. Non-steroidal anti-inflammatory drugs are contraindicated in severe burns within the first 48 hours due to the increased risk of renal failure and gastric stress ulcers. Benzodiazepines may help with anxiolysis and avoid hypotension.

TEMPERATURE REGULATION

Hypothermia following burns can be significant and may result in worse outcomes. Children with large burns, full-thickness burns, inhalation injury or those who are intubated are at risk for hypothermia and benefit from any measures for temperature preserving[31]. The most critical time is during burn debridement and grafting, and many clinical practice guidelines recommend the ambient temperature should be increased in the operating room and intensive care unit. The use of an intravenous fluid warmer is a novel way in maintaining normothermia during the surgery in burn patients and may be more effective than conventional methods[32].

HYPERMETABOLIC STATE: IMPORTANCE OF ADEQUATE NUTRITION

A burn injury results in a prolonged and persistent hypermetabolic response characterised by a 10- to 20-fold elevation in plasma catecholamines, cortisol and inflammatory mediators.

This response leads to twice-normal metabolic rates and whole-body catabolism. Adequate nutrition is therefore an essential part of burn care and should be initiated within 12h after injury[33]. Early enteral nutrition mitigates catabolism and recommendations exist for nutrition that is high in glucose and amino acids, and low in fat with some unsaturated fatty acids.

Supplementation of single aminoacids, especially alanine and glutamine has debatable effect[35]. Dietary components that have gained more recent attention are vitamins, micronutrients and trace elements and their replacement may reduce morbidity in patients with severe burns[36].

PREVENTING INFECTIONS

Infection remains the leading cause of death in patients with severe burns. Prophylactic parenteral administration of antibiotics is not recommended, but targeted therapy according to the results of microbiological analysis. Prophylactic systemic antibiotics can be convenient in patients with severe burns who require mechanical ventilation and in selected split-thickness skin grafting procedures[37]. The use of topical antimicrobial agents is important in the treatment of local infections because systemic antibiotics do not reach burns in high concentrations due to vascular microthrombosis and the presence of oedema. Silver sulfadiazine with cerium nitrate is usually first line therapy and may be effective for up to 48 hours[38].

ANESTHESIA FOR SURGICAL PROCEDURES

Damaged tissue releases toxins and pro-inflammatory mediators responsible for systemic inflammatory response syndrome (SIRS) and hypermetabolism. Surgery may need to be performed on a regular basis, with an average of one operation every 5-7 days. The risks of septic shock, renal failure and multiple organ failure also increase exponentially with time[38].

Patients are often brought to the operating room in the early phase of burn injury, when they are undergoing significant fluid shifts with corresponding cardiovascular and/or respiratory instability[39]. However unstable the child is, the operation should not be delayed as early wound excision and coverage with skin analogues within 72–168 hours, improves outcome in paediatric patients with acute burn without inhalation injury. Lower doses of anaesthetic drugs may be required as decreases in circulatory blood volume throughout the first phase (first 48h) of burn shock leads to reduction in renal and hepatic blood flow which prolongs the rate of drug distribution and the onset of clinical effects. In the following hypermetabolic state (after 48h), high blood flow to the liver and kidneys, decreased plasma albumin and an increased level of α-1-acid glycoprotein results in modulated protein binding and elevated renal clearance[40].The amount of albumin to which acidic and neutral drugs bind decreases, so the free fraction is higher, but the amount of α-acid glycoprotein that binds cationic drugs is doubled (lidocaine, propofol, muscle relaxants, some opioids) and thus the free fraction decreases.

General anaesthesia with the use of opioids, volatile or intravenous anaesthetics and muscle relaxants, is common choice of anaesthesia for burn excision and grafting. Propofol and thiopental are successfully used for induction with careful titration, in order to minimize dose-dependent respiratory and cardiac depression.

Etomidate is not a good choice due to the possibility of inducing adrenocortical suppression. Ketamine can be advantageous for the induction of hypovolemic patients because of sympathetic nervous system stimulation and may be useful for procedural sedation for a change of dressing[41]. Anaesthesia maintenance is reached with inhalational agents or with intravenous anaesthetics. Succinylcholine can be safely given within the first 24 hours of injury. However, should not be used after 48–72h post-burn injury, due to synthesis of extrajuctional receptors causing hyperkalaemia. There may also be a degree of resistance to nondepolarizing muscle relaxants[42].

While regional anaesthesia techniques offer great benefits for pain control, it may be hard to find an intact skin area for regional anaesthesia in the child with severe burns[43].

CONCLUSION

Severe burn-related injuries require a multidisciplinary team assessment and management. Understanding and applying the principles of the initial approach in burned children can help to improve outcomes. Particular attention should be directed to airway management, fluid and metabolic requirements, and appropriate analgesia and sedation. New initiatives to tackle the problem of antibiotic resistance are required urgently.

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Update in
Anaesthesia

Paediatric cardiogenic shock

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Abstract

Shock is a state of acute circulatory failure characterised by tissue perfusion inadequate to meet the needs of the body. It rapidly leads to multi-organ failure and death if not recognised and treated early. In its simplest form, cardiogenic shock is considered "pump failure" with structural heart disease, arrhythmias and myocarditis recognised causes in children. Maximizing myocardial performance by optimising the preload, contractility and minimising afterload and enhancing systemic oxygen delivery are essential in the treatment of this high mortality condition.

Key words: shock; cardiogenic; paediatric

SHOCK - DEFINITION AND CLASSIFICATION

Our understanding of the complex phenomena that is shock is constantly evolving. Defined as an acute state of circulatory failure characterised by tissue perfusion inadequate to meet the needs of the body, it rapidly leads to multi-organ failure and death if prolonged. The recognition of shock and early initiation of treatment is therefore essential. However, this can be very difficult in paediatric practice. The presence of multiple paediatric clinical shock definitions (e.g. WHO, FEAST criteria, APLS) or those based on SIRS criteria and age based parameters, coupled with the large amount of inter-observer variability during clinical assessment make diagnosis of paediatric shock problematic. The shock definition in adults is less subjective, defined as it is by the presence of hypotension and a lactate rise.

The complexity of recognising a "pre-shocked" state and the known increased mortality with fluid bolus therapy mean diagnosing and treating shock in a child, especially in a resource limited setting, is challenging.

Many conditions can ultimately lead to a state of shock. It can be broadly classified by pathophysiology (Table 1). Certain conditions, such as sepsis, can lead to more than one type of shock.

SHOCK PHYSIOLOGY

Understanding the physiology of shock enables a greater appreciation of treatment options and the ability to explain the clinical features seen. At its core, is an unbalancing of the relationship of oxygen consumption (VO_2) to that of oxygen delivery (DO_2).

$$\mathbf{VO_2 = DO_2 \times O_2\,ER}$$

- **VO_2** = Oxygen consumption is the total amount of oxygen removed from the blood due to tissue oxidative metabolism per minute. The value cannot be measured directly but can be assessed by measuring the amount of oxygen delivered on the arterial side compared to the amount on the venous side. Oxygen consumption Index (VO_2I) calculated using cardiac index rather than cardiac output
- **DO_2** = Global oxygen delivery is the total amount of oxygen delivered to the tissues per minute, irrespective of the distribution of blood flow
- **O_2ER** is the oxygen extraction ratio (ratio of VO_2 to DO_2)

At rest, DO_2 is more than adequate to meet VO_2 and ensure that aerobic metabolism is maintained. Paediatric DO_2 ranges from 160 to 804ml/min^2 and oxygen consumption index values range from 120 to 200ml/m^2. O_2ER is 25% and varies for different organs. Oxygen that is not extracted returns to the mixed venous circulation. A $ScvO_2$ (central venous oxygenation saturation) of 70% indicates oxygen delivery is adequate.

As $V0_2$ increases or DO_2 decreases, O_2ER rises to maintain aerobic metabolism and oxygen consumption remains independent of oxygen delivery. At 'critical DO_2' however, the maximum O_2ER is reached. Beyond this point, any further increase in VO_2 or decline in DO_2 leads to tissue hypoxia and anaerobic

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Table 1: Causes of shock

Cardiogenic shock	Obstructive shock	Hypovolaemic shock	Distributive shock
Impaired contractility - Myocardial ischaemia and complications, including congenital heart disease - Myocarditis - Septic shock - Poisoning or toxic exposure - End stage cardiomyopathy	*Within the circulatory system* - Massive pulmonary embolus	Haemorrhage *Fluid loss* - GI losses (vomiting, diarrhoea, short gut, etc) - Excessive diuresis (diabetes insipidus, diuretics) - Excessive diaphoresis (heat-related illness) - Diabetic ketoacidosis/Burns/ Third spacing (pancreatitis, severe sepsis, anaphylaxis)	Neurogenic shock Liver failure Adrenal insufficiency Anaphylaxis Septic shock Post-bypass vasoplegia *Drugs and toxic exposures* - e.g. calcium channel blockers, epidural anaesthesia
Dysrhythmia - Tachycardias/Bradycardias	*External to the circulatory system* - Cardiac tamponade - Abdominal compartment syndrome - Tension pneumothorax		
Valvular dysfunction			
Left ventricular outflow tract obstruction - Hypertrophic cardiomyopathy			

metabolism. Cellular metabolism becomes much less efficient in a stressed state, resulting in the accumulation of lactic acid. This will eventually lead to cell dysfunction, acidosis and cell death.

Oxygen delivery (DO_2) is the product of cardiac output (CO) and arterial oxygen content.

$$DO_2 = CO \times CaO_2$$

$$CO = HR \times SV$$

$$CaO_2 = (Hb \times SaO_2 \times 1.34) + (0.003 \times PaO_2)$$

- DO_2 depends on the cardiac output, and the arterial content of blood (CaO_2)
- Cardiac output is dependent upon heart rate (HR) and Stroke Volume (SV)
- The CaO_2 depends on how much oxygen carrying capacity is available, which is primarily a function of the haemoglobin (Hb) level and the arterial oxygen saturation (SaO_2). PaO_2 is the partial pressure of oxygen in arterial blood. A small, usually insignificant amount of oxygen is directly dissolved in the blood rather than bound to Hb.
- 1.34 is the amount of O_2 that can combine with 1gram of haemoglobin (Oxygen carrying capacity has been referenced between 1.34-1.39). Called Hüfner's constant.
- 0.003: Dissolved oxygen in plasma is determined by the solubility coefficient of oxygen at body temperature and the PaO_2 (mmHg)

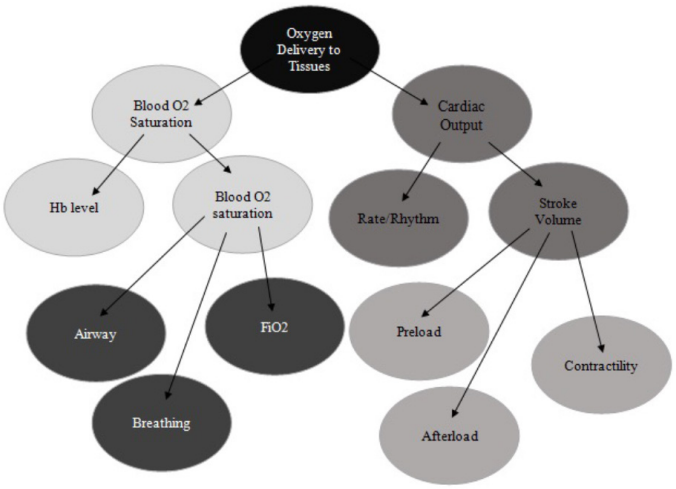

Figure 1: Determinants of oxygen delivery

Causes of reduced oxygen delivery

- Hypoxia, anaemia, poor contractility, shock, abnormal heart rate or rhythm

Causes of increased oxygen consumption

- Fever and inflammatory states eg sepsis, burns, trauma, increased metabolic rate, increased muscular activity, increased respiratory effort

Causes of impairment of the extraction or utilization of oxygen by cells

- Sepsis, cyanide poisoning

Table 2: Causes of cardiogenic shock

Heart rate abnormalities	Congenital heart defects	Cardiomyopathy
• Supraventricular tachycardias • Ventricular dysrhythmias • Bradycardia	• Lesions with ductal dependent systemic blood flow in neonates (Coarctation of Aorta, Critical Aortic Stenosis, Interrupted Aortic Arch, Hypoplastic Left Heart Syndrome) – neonatal presentation usually • Lesions with increased pulmonary blood flow – Atrial Septal Defect, Ventricular Septal Defect, Patent Ductus Arteriorus, Atrioventricular Septal Defect • Lesions with reduced pulmonary blood flow – Tetralogy of Fallot • Ischaemic cardiomyopathies (e.g. Anomalous Left Coronary Artery from Pulmonary Artery) • Congenital heart defects that present with shock are those that have obstruction to flow from the left ventricular tract and occasionally those with large left to right shunts.	• Hypoxic ischaemic events • Infectious • Metabolic e.g. hypothyroid, acidosis, hypocalcaemia • Connective tissue disorders e.g. Rheumatic fever, • Neuromuscular disorders e.g. Duchenne Muscular Dystrophy • Toxic reactions e.g. chemotherapy • Other - Familial or idiopathic dilated

The overall goal in the treatment of shock is to maximise oxygen delivery to the cells and minimise oxygen consumption (Figure 1).

- Stroke Volume (SV) is a function of preload, afterload, contractility and diastolic relaxation. Therefore optimising heart rate (HR), contractility, diastolic relaxation, preload and afterloa improves cardiac output (CO).
- Oxygen carrying capacity can be increased by raising haemoglobin and optimising its saturation with oxygen.
- Systemic oxygen delivery can be improved by manipulation of all these factors.
- A reduction in oxygen consumption can be achieved in a number of ways, including intubation and ventilation, sedation and temperature control.

CARDIOGENIC SHOCK

In simple terms, cardiogenic shock is considered "pump failure". Myocardial dysfunction, usually systolic, is responsible for the failure of the cardiovascular system to meet the metabolic demands of the body. Occasionally diastolic dysfunction can cause cardiogenic shock, including post operatively or during ischaemia from certain cardiac lesions. It is the most advanced stage of heart failure and is lethal in 5 – 10% of cases. Outcomes are highly variable and dependent upon the extent and nature of the underlying myocardial insult, co-morbidities and promptness of myocardial support.

The numerous causes of cardiogenic shock can be classified into three broad categories (Table 2).

PATHOPHYSIOLOGY

Cardiogenic shock can lead to a progressive fall in myocardial function if not identified and corrected early (figure 2). Reduced myocardial contractility leads to a rightward shift of the left ventricular end-systolic pressure volume curve and a fall in stroke volume. A metabolic acidosis can develop which may impair

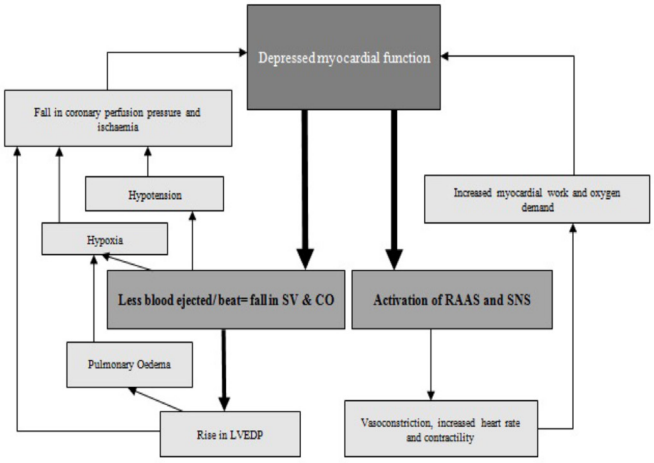

Figure 2: Pathophysiology of cardiogenic shock

contractility further. Hypotension may ensue, prompting a fall in coronary perfusion pressure and subsequent myocardial ischaemia. A rise in left ventricular end diastolic pressure (LVEDP) from diastolic dysfunction causes decreased myocardial perfusion pressure and pulmonary oedema, contributing to hypoxemia and myocardial ischaemia. A downward spiral of failing myocardium and worsening myocardial ischaemia can be difficult to break and reverse. Significant arterial oxygen desaturation often occurs in cardiogenic shock as a result of a decrease in mixed venous oxygen saturation (SVO_2) and intrapulmonary shunting. SVO_2 decrease occurs as a result of increased tissue oxygen extraction because of the low CO.

In addition as systemic perfusion falls, compensatory neurohumeral mechanisms are activated. An increase in systemic vascular resistance via the renin-angiotensin-aldosterone system (RAAS) and sympathetic stimulation causes an increase in heart rate and contractility. This can be counterproductive, increasing the afterload

on the heart and a rise in myocardial oxygen demand. As a result, blood flow is redistributed from nonessential vascular beds such as the skin and skeletal muscles, to the brain, heart and lungs. Blood pressure is therefore a poor indicator of cardiovascular status in paediatric patients due to this prolonged compensatory regulation of vascular tone.

CLINICAL FEATURES

Clinical findings depend upon the aetiology, presence of co-morbidities, degree of shock, and the patient's age. Tachycardia is the main compensatory mechanism to maintain the CO and systemic perfusion. Nonspecific signs of shock suggestive of poor perfusion include oliguria, cyanosis, cold extremities, weak distal pulses, lethargy or altered mentation and hypotension. Signs of heart failure may give a hint to the cause being cardiogenic shock. These include irregular pulse, narrow pulse pressure, hepatomegaly, distended jugular vein, heart murmur, gallop rhythm, distant heart sounds and pulmonary crackles. Infants may present with difficulty feeding, while older children may complain of difficulty breathing and chest pain.

INVESTIGATIONS

Cardiogenic shock is an emergency. Simultaneous history and examination with rapid clinical diagnosis and initiation of treatment is essential. Investigations should not delay management (table 3). They however should be undertaken if available and are necessary for a number of reasons. Investigations can determine the cause and severity of disease, assess the functional status of the myocardium, direct the treatment and assess its therapeutic response.

MANAGEMENT

The goals of management of a patient in cardiogenic shock are three-fold:

1. Minimise oxygen demand/consumption
2. Maximise myocardial performance and systemic oxygen delivery
3. Treat underlying cause

Early recognition and immediate administration of resuscitation therapies are the primary aims of initial management to prevent worsening organ dysfunction by restoring adequate oxygen delivery to peripheral tissues. Resuscitation should commence even whilst investigation is ongoing to identify and rapidly treat reversible causes. Management of cardiogenic shock in certain congenital heart diseases is discussed elsewhere and involves balancing the pulmonary and systemic circulations.

A simplified approach using the Airway, Breathing, Circulation technique is best utilised in the management of a patient with cardiogenic shock. Optimisation of all components in figure 1 is vital. The goal is to maximise oxygen delivery whilst reducing oxygen consumption and myocardial work load.

- *Airway*
  - If able to maintain – give oxygen with positive end expiratory pressure (PEEP) aim >92% saturation
    - PEEP has both advantages and disadvantages in cardiogenic shock. Not only can it increase airway pressure and improve oxygenation and alveolar recruitment, but also decrease left ventricular afterload due to decreased LV transmural pressure. However, PEEP can lead to decreased cardiac output through its effects on the right heart (decreased RV preload and increased RV afterload), especially if co-existent hypovolaemia.
    - Can be given via T piece or self-inflating bag with peep valve
  - If apnoeic or unstable airway – plan early intubation using ketamine and rocuronium
  - If patient requires intubation, this is a very high-risk situation
    - Avoid use of induction medications that adversely affect myocardial contractility as much as possible. Caution should also be taken in the use of positive pressure ventilation due to its effects on the right heart with possible reduction of preload and increased afterload. Efforts to avoid apnoea are very important as it exacerbates the coexistent acidemia
    - Consider commencing peripheral inotropes (such as adrenaline) prior to induction to improve myocardial contractility and use small aliquots of fluid boluses.
    - Ketamine proves to be the ideal first choice for induction for it is the least cardio-depressant agent widely available. Should be used with caution in those with chronic heart failure.
    - Prepare for a possible cardiac arrest – allocating team members and ensure resuscitation dose adrenaline is prepared.
- *Breathing*
  - Use of non-invasive or invasive ventilation may be required to augment cardiac function and reduce oxygen consumption, diverting oxygen delivery to areas that need it most. Positive pressure ventilation can be beneficial through improvement of blood gas tension, reduction of work of breathing and afterload reduction to the left heart.
  - Supplement ventilation with assisted breaths and addition of positive end expiratory pressure
  - Monitor oxygen saturations, ensure >92%
- *Circulation*
  Goal is to optimise preload, afterload and contractility
  - Obtain IV access.
  - Assessment of fluid status – optimise preload
    - If evidence of dehydration
    - Used of volume expansion with small fluid boluses (5-10mL/kg)

Table 3: Investigations for cardiogenic shock

Investigation	Findings
Chest X-ray	• Perhaps the most readily accessible imaging required in the management of cardiogenic shock in resource limited settings. • Can diagnose air leak syndromes (pneumothorax, pneumomediastinum), assess lung parenchyma and vessels and exclude other causes of shock or chest pain. • Signs of pulmonary oedema of cardiogenic origin (perihilar fluffy opacities with butterfly/bat wing patterns) can be detected and cardiomegaly may give a clue towards the underlying aetiology. • Pericardial effusion, with its characteristic water bottle sign along with typical clinical findings, can be easily detected. • A boot-shaped heart suggests right ventricular dilatation.
Electrocardiography (ECG)	• Can elude to certain structural diseases, such as the anomalous origin of the left coronary artery arising from the pulmonary artery (ALCAPA), or acute conditions (e.g., pericarditis, myocarditis) • Detect rhythm disorders resulting in cardiogenic shock.
Echocardiography	• Essential to diagnose anatomic abnormalities, ascertain functional status, and for follow-up assessment of response to therapy. • Goal-directed echocardiography (GDE) aims to rapidly help assess cardiac anatomy and function in the patient with haemodynamic failure to guide subsequent therapy. Five views including the parasternal long-axis, parasternal short-axis, apical four-chamber, substernal, and inferior vena cava (IVC) views are performed. In addition, color Doppler analysis of the mitral and aortic valves may also be considered.
Blood gas and electrolytes	• Can help differentiate acute from chronic congestive heart failure (CHF). Metabolic acidosis and lactic academia are usually present in patients with acute CHF with low cardiac output, while pH is usually normal and partial pressure of carbon dioxide ($PaCO_2$) low in case of chronic CHF. • It is recommended to repeatedly obtain arterial pH and blood lactate levels to assess the course of shock and evaluate the efficacy of therapy. • A decrease in tissue perfusion can lead to hypokalemia and lactic acidemia • Mixed venous oxygenation (SVO_2) and its serial measurements can give an indication of cardiac output. • Patients on diuretic therapy should be regularly monitored for hyponatremia and hypochloremia through electrolyte analysis.
Other laboratory tests	• Renal and liver function tests help to determine the adequacy of end-organ perfusion. • Complete blood count will reveal anemia; low haemoglobin can increase left to right shunt by reducing the pulmonary vascular resistance, and hence worsen the clinical picture of failure. • Essential to rule out hypoglycemia and hypocalcemia in neonates with left ventricle failure, • Creatine phosphokinase- MB (CPK-MB) and troponin I levels can help to diagnose myocardial ischaemia. • The determination of B-type natriuretic protein (BNP) is widely used to assess the severity of cardiac involvement, particularly in patients with preexisting cardiomyopathy, in the diagnosis of congenital heart disease and heart failure and monitoring postoperative hemodynamics in cardiac surgery patients. • Anti-dsDNA and antinuclear antibody (ANA) assays can rule out autoimmune disorders. • Abnormalities of lactate, glucose and carnitine can inform the diagnosis of a mitochondrial cardiomyopathies. • Urine analysis may reveal albuminuria, increase in urine specific gravity, and microscopic hematuria. The presence of methylglutamic aciduria implies a metabolic cause of failure.
Cardiac catheterization	• Provides functional data of the failing myocardium and identifies structural abnormalities and/or microbial causes of cardiogenic shock.

- If evidence of fluid overload
- Diuretics and maintenance fluid restriction (50mls/kg/day)
- Cautious fluid administration in those with malnutrition. See WHO ETAT guidelines
- Constant clinical reassessment of fluid status

- Ensure adequate haemoglobin
  - Red cell transfusion may improve preload and oxygen delivery
- Ensure normal heart rhythm
  - Cardioversion or cautious administration of anti arrhythmics may be required
- Vasoactive Agents – optimise afterload and contractility
  - Vasopressors
  - Inotropes
  - Vasodilators
- Resuscitation dose of Adrenaline
  - 10mcg/kg (0.1ml/kg of 1 in 10,000 solution)

• *Additional*
- Prostaglandin (PGE1) therapy
  - Used to maintain ductal patency in newborns and young infants with shock secondary to duct dependent congenital heart defects.
  - Maintains systemic circulation through the patent ductus arteriosus
  - Infusion dose is 0.05-0.1mcg/kg/min. Hypotension and apnea are important side effects.
- Normothermia
  - Avoid hypothermia and fever.
- Nutrition
  - If the acute phase and resuscitation are passed, nutrition should be optimized to maintain daily calorie and protein intake. The calorie requirement in infants can be up to 130-170 cal/kg/day
- Frequent weights are important to assess fluid balance status
- Review investigations and treat underlying cause

Although fluid resuscitation to correct hypovolemia and hypotension is often one of the most important initial steps, it is indispensable to highlight that goal-directed therapy should be based on continuous clinical, laboratory and echocardiographic assessment. The increased mortality with fluid bolus therapy in children from Sub-Saharan Africa (FEAST trial) highlights that this can no longer be considered a benign therapy, especially in settings lacking critical care expertise and facilities.

Continuous monitoring of patients is essential. Placement of an arterial catheter for monitoring of blood pressure and blood sampling, plus a central venous catheter for the infusion of fluids and vasoactive agents is desirable.

Diuretics are indicated when ventricular dysfunction is associated with fluid overload to relieve systemic and pulmonary vascular congestion. Common classes used include loop diuretics, thiazide, and aldosterone antagonists. Furosemide, a loop diuretic drug with rapid onset of action of 2-5 minutes and duration of action of 3 hours, is by far the widely used drug. It can be administered as a bolus or as a continuous infusion with the latter option being associated with less hemodynamic instability and electrolyte imbalances. Adverse effects of furosemide include hypokalemia, metabolic alkalosis, hypocalcemia and hyponatremia.

Vasoactive agents

Many vasoactive drugs have both vasopressor and inotropic actions (table 4). The choice is guided by matching the therapeutic goals with the mechanism of action of different agents. Catecholamines comprise the mainstay for inotropic and/or vasopressor support in the setting of cardiogenic shock, where their inotropic effect promotes increased cardiac output by improving myocardial contractility through engaging ß1receptors. The understanding of underlying pathophysiologic mechanisms and the mode of action of available agents are essential for a goal-directed therapy. Dopamine may be the first option to treat mild to moderate cardiogenic shock. Milrinone or dobutamine is the first choice to treat acute severe cardiac failure in the absence of hypotension. If cardiogenic shock is complicated by severe hypotension, epinephrine or norepinephrine is preferred depending upon the haemodynamics and myocardial function.

Digoxin

- An inotrope and exerts its effects by binding to and inhibiting sodium-potassium ATPase. This inhibition results in an increase in intracellular calcium, hence enhanced myocardial inotropic state and a slowing of the heart rate.
- Has a narrow therapeutic window, long half-life and multiple side effects and this toxicity rather limits its use in certain circumstances.

Vasodilators

This category includes nitrated derivatives, angiotensin-converting enzyme (ACE) inhibitors (captopril, enalapril) and angiotensin II receptor blockers (ARBs) and hydralazine. Vasodilators can improve the cardiac function by favorably altering afterload and preload but they are not generally advisable for use to treat acute cardiogenic shock.

Mechanical Circulatory Support (MCS)

Extracorporeal life support (ECLS) and ventricular assist devices (VADs) are the two forms of mechanical circulatory support currently available in certain centres to infants and children with cardiogenic shock not amenable to conventional therapy.

Table 4: Pharmacology and relative potency of inotropes and vasopressors commonly used in shock

Drug	Dose	Effect					Additional Notes
		Cardiac ((ß1)		Peripheral vasculature		Dopaminergic	
		HR	contractility	Vasoconstriction (α1)	Vasodilation (ß2)		
Dopamine (short)	1-5mcg.kg^{-1}.min^{-1}	1+	1+	0	1+	4+ (located in the brain and in vascular beds in the kidney, mesentery, and coronary arteries)	
	6-10mcg.kg^{-1}.min^{-1}	2+	2+	1+	0	2+	
	11-20mcg. kg^{-1}.min^{-1}	2+	3+	3+	0	2+	
Dobutamine	1–20mcg. kg^{-1}.min^{-1}	2+	3-4+	0	2+	0	Causes mild vasodilatation, increases the CO, and reduces the SVR, with minimal alteration of BP and HR and does not alter or impair renal flow
Epinephrine	0.01-1mcg.kg^{-1}.min^{-1}	4+	4+	4+	3+	0	Higher concentrations are detrimental to myocardial function with increased oxygen consumption out of proportion to the increase in force of contraction
Norepinephrine	0.01-1mcg.kg^{-1}.min^{-1}	1+	2+	4+	0	0	
Phenylephrine	0.1-0.5mcg.kg^{-1}.min^{-1}	0	0	3+	0	0	
Milrinone (PDE-I)*	0.1-1mcg.kg^{-1}.min^{-1}	1+	3+	0	2+	0	Selectively inhibits phosphodiesterase III. Used as both inotrope and vasodilator to reduce preload and afterload. Possible adverse effects include hypotension especially in patients with a relative depletion of intravascular volume and those with renal dysfunction in whom drug clearance is reduced.

* Milrinone is a phosphodiesterase inhibitor (PDE). Its effects (inotropy and vasodilation) are independent of α or ß- receptors.

CONCLUSION

Cardiogenic shock is an uncommon, but important cause of paediatric shock. It has a high mortality and early recognition is essential. Interventions to maximise oxygen delivery whilst reducing oxygen consumption form the basis of critical care management.

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Update in
Anaesthesia

The child with severe tetanus

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Abstract

Tetanus is an infectious disease which cannot be totally eradicated because the spores of the infecting organism are ubiquitous. It is however entirely preventable by immunization. It is still a health problem in the low-income countries with high neonatal mortality rates reported. It is also a cause of childhood mortality. In its severe forms, it is a multi-systemic disease affecting the autonomic, respiratory, cardiovascular and renal systems requiring multidisciplinary management in a neonatal or paediatric intensive care unit. The course of the disease may be prolonged, and the late sequelae of the disease may contribute significantly to morbidity in the growing child.

INTRODUCTION AND EPIDEMIOLOGY

Tetanus is a vaccine preventable toxin-mediated highly fatal disease of the nervous system characterised by muscle rigidity and painful muscle spasms.

It is a disease of the poor, the uneducated and those with adverse social circumstances. In low-income countries, it is common in the neonatal period in newborns whose mothers did not have their routine tetanus immunization during pregnancy as well as unhygienic deliveries taking place at home with unsterile umbilical cord practices. Effective immunization has reduced the incidence of neonatal tetanus significantly in high-income countries.

The World Health Organization (WHO) estimated that neonatal tetanus caused death of 30,848 newborns in 2017 which was a 96% reduction from an estimated death of 787,000 newborns in 1988. As the universal coverage of vaccine increases, the prevalence of tetanus has been found to drop.

Worldwide, all countries are committed to Maternal and Neonatal Tetanus Elimination (MNTE). As tetanus cannot be eradicated, the initiative aims to reduce maternal and neonatal tetanus by ensuring immunization of children, mothers, women of reproductive age as well as promotion of hygienic deliveries and cord care practices. As at July 2019, 12 low-income countries had still not eliminated MNTE. There is continuing progress in these countries and it hoped that many more will achieve total elimination in the near future.

Post-neonatal tetanus is also a cause of morbidity and mortality in children aged 1 – 10 years with a prevalence rate of 0.48% reported in North India and 0.67% reported in Southern Nigeria. Management of the severe forms should be in a paediatric intensive care unit (PICU). In spite of its availability in some low-income countries, mortality continues to be on the rise. Childhood vaccination especially the booster doses of the vaccine should be routinely administered to prevent the disease scourge.

PATHOPHYSIOLOGY

Tetanus is caused by Clostridium tetani, a motile, gram positive, spore-forming obligate anaerobe. It is ubiquitous; commonly found in soil but has also been found in human and animal faeces. The spores can survive for months to years and are resistant to boiling and disinfection. It can however be destroyed by autoclaving at 12^{0o}C for 15 minutes at 1 atmospheric pressure.

In infected or necrotic tissue, anaerobic metabolism occurs, allowing the organism to secrete two toxins: tetanolysin and tetanospasmin.

Tetanolysin damages the surrounding viable tissue and optimizes conditions for bacterial multiplication. It causes permeability changes in biological membranes causing cell lysis.

Tetanospasmin is responsible for the clinical syndrome of tetanus. It is one of the most lethal toxins known, having an estimated minimum lethal dose of $2.5ngkg^{-1}$. It enters the nerve terminals through the lower motor neurons responsible for initiating voluntary muscular movements.

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It then travels by retrograde axonal transport to the spinal cord and brainstem.

Here, the toxin exerts its effects by cleaving synaptobrevin, a vesicle-associated membrane protein which is responsible for release of neurotransmitters. The toxin primarily affects inhibitory neurons preventing the presynaptic release of gamma-aminobutyric acid (GABA) and glycine. These neurons keep overactive motor neurons from firing and also play a role in the relaxation of muscles after contraction. There is thus loss of inhibitory actions on motor and autonomic neurons. With this loss, there is uncontrolled muscle contractions as well as autonomic hyperactivity responsible for the ever-present features of muscle spasms and autonomic dysfunction. Other theories have however been suggested to cause autonomic dysfunction including damage to the brainstem and hypothalamic nuclei. Autonomic dysfunction was considered to be only sympathetic overactivity, but studies with haemodynamic monitoring have shown that both sympathetic and parasympathetic systems are involved.

Once the toxins are affixed to the neurons, they cannot be neutralized by antitoxins. Recovery of nerve function is dependent on regeneration of new nerve terminals and formation of synapses which explains the prolonged duration of tetanus.

Localized tetanus occurs when the nerves supplying the muscle of the contaminated site is involved. With a high toxin load, there is haematogenous and lymphatic spread to multiple nerve terminals resulting in generalized tetanus. Cerebral neurons are spared because the toxins do not reach the cortical neurons by the retrograde axonal transport and do not pass the blood brain barrier to gain access from the bloodstream. Because of this, patients with tetanus are often conscious. Involvement of the lower cranial nerves has been suggested to result from their relation to area postrema on the floor of the fourth ventricle where the blood-brain barrier does not exist.

CLINICAL PRESENTATION IN CHILDREN

Tetanus is one of the very few diseases in which the clinical presentation is characteristic and sufficient enough to make a clinical diagnosis. There are presently no serologic tests to confirm the diagnosis. Laboratory studies are only required to follow up some of the expected complications.

It usually follows a recognized abrasion, cut, wound or bite in a child.

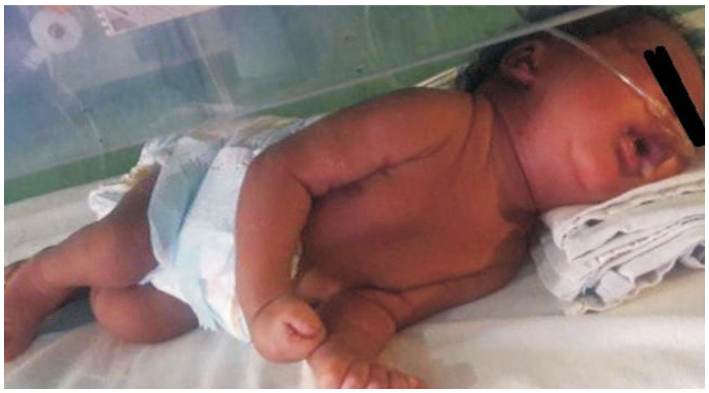

Figure 1: Severe spasms with flexion of the arms in neonatal tetanus. Reproduced by permission from Department of Paediatrics, Lagos University Teaching Hospital (courtesy Dr O.O Majiyagbe)

The injury may have been sustained during outdoor play and healed at the time the child developed symptoms as the child failed to report it to his or her caregiver for fear of reprimand. In 50% of cases, the injury may occur indoors, considered trivial and medical attention is not sought. Other times (15 – 25% of cases) the injury may go unrecognized. It has been associated with ear infection in children with otorrhea being the only plausible symptom, intramuscular injection abscess and burns. In the neonate it usually follows delivery at home or with traditional birth attendants with unhygienic umbilical cord practices in the unvaccinated mother.

Classification

Four clinical types of tetanus have been described: Localized tetanus involves the muscles surrounding the portal of entry. There is a low toxin load and therefore spasms and rigidity are restricted to these group of muscles. Mortality is low. Cephalic tetanus is a form of localized tetanus involving the facial muscles. It occurs in tetanus following head wounds or otitis media. It rapidly progresses to generalized tetanus and has a high mortality. Neonatal tetanus is the most fatal form as it causes more than 50% of deaths from tetanus worldwide. It occurs in neonates and is usually generalized. Generalized tetanus is the most common form of tetanus found in children outside the neonatal period. It is also referred to as post-neonatal tetanus in children.

Natural History

Following injury and colonization of the bacilli, the first symptom of tetanus occurs within 7 – 10 days, with a range of 1 – 60 days. This is the incubation period (from injury to first symptom). This interval is a reflection of the distance the toxin travels to the nervous system and is related to the quantity of toxins released. The first symptom is often trismus (lockjaw) which is due to contraction of the masseter muscle. The onset time is from the first symptom to the first spasm and occurs within 1 – 7 days. A short incubation period and onset time are associated with severe disease and poor prognosis.

The features of tetanus are a triad of muscle rigidity (from increased muscle tone), spasms and when severe, autonomic dysfunction. The manifestations of tetanus assume a descending form; trismus or lock jaw (from masseter muscle spasm), neck stiffness, dysphagia, and

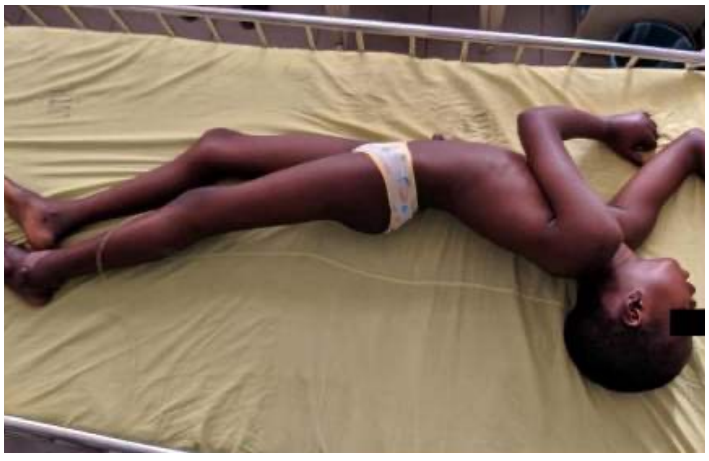

Figure 2: Opisthotonus position in a child with severe tetanus. Portal of entry was a head wound which had healed at presentation

board-like rigidity of the abdomen are often early symptoms. Spasms of the facial muscles cause the typical wry smile – risus sardonicus. Rigidity of the neck muscles lead to retraction of the head while truncal rigidity and preponderance of extensor muscle contraction leads to opisthotonus posturing.

Spasms are excruciatingly painful and progressively affect other muscle groups with a convulsive-like appearance. They may occur spontaneously, or be triggered by touch, visual or auditory stimuli. Spasms may be severe enough to cause long bone fractures and tendon avulsions. Laryngeal spasms will cause acute airway obstruction with hypoxia and death ensuing. Spasms may persist for 2 – 3 weeks or may be longer. Autonomic dysfunction usually starts several days after the spasms and reaches a peak during the second week of the disease. In neonates however, it occurs during the first week of the illness possibly because of their short axonal length. Rigidity usually lasts beyond the duration of both spasms and autonomic dysfunction.

The affected neonate would have established sucking after birth, but stops sucking, is irritable and has a fixed wry smile on the face. This is followed by rigidity, spasms, fever and difficulty in breathing. There may be evidence of umbilical cord sepsis such as hyperaemic and foul-smelling umbilical cord. Death will occur by the end of the first week if management is not instituted.

Severity grading of tetanus

Several grading systems have been described which serve as an index of severity. The Dakar score is commonly used in neonates while the system reported by Ablett is the most widely used in older children.

Even with the advent of mechanical/artificial ventilators to manage the respiratory complications of severe tetanus, many children still die. This is from autonomic disturbances which can be life-threatening. It presents as labile hypertension, persistent tachycardia and vasoconstriction with sweating, bradycardia, cardiac arrhythmias, hypotension and fever. Autonomic storms may occur with marked cardiovascular instability; severe hypertension and tachycardia may alternate with profound hypotension and bradycardia with recurrent cardiac arrest. Other autonomic effects include profuse salivation and increased bronchial secretions, gastric stasis, ileus and diarrhea. Tetanus is a multi-systemic disease with its direct effects on some organ systems when severe:

Altered respiratory physiology

Ineffective cough mechanisms from rigidity and spasms lead to atelectasis, subsequent pneumonia and Type I respiratory failure. Pharyngeal and laryngeal spasms will cause life threatening airway obstruction and Type II respiratory failure. Muscular rigidity and spasms of the chest wall, diaphragm and abdomen lead to a restrictive defect contributing to the ventilation perfusion mismatch. Prolonged spasms as well as altered brain stem function may lead to sudden or repeated apnoea. The neonate often presents with apnoea. The inability to swallow saliva, profuse bronchial secretions, pharyngeal spasms, raised intraabdominal pressure, gastroparesis from autonomic dysfunction all increase the risk of aspiration.

Altered cardiovascular physiology

The effect on the cardiovascular system is from sympathetic nervous hyperactivity, toxic myocarditis and medullary effects.

Sympathetic nervous hyperactivity causes labile hypertension, tachycardia, arrhythmias, high oxygen consumption, peripheral vascular constriction, intense diaphoresis, pyrexia and increased urinary catecholamine excretion. It is integral in severe cases of tetanus. Cardiac output is high but there is low to normal systemic vascular resistance because of extensive vasodilatation in metabolically active muscles. Refractory hypotension unresponsive to fluids and vasopressors has been associated with a direct effect of the toxin on the myocardium – toxic myocarditis. Sudden cardiac failure has been associated with medullary damage in the brainstem. Pyrexia in the absence of infection has been attributed to disturbance of the temperature regulating center.

Altered renal physiology

There is a reduction in glomerular filtration rate and impaired tubular function due to alteration of renal blood flow from catecholamine surges, rhabdomyolysis from severe spasms, dehydration and sepsis.

Table 1: Dakar Score

Prognostic factor	**Score 1**	**Score 0**
Incubation period	<7 days	≥7 days or unknown
Onset time	<2 days	≥2 days
Entry site	Umbilicus, burns, open fracture, surgical wound, intramuscular injection	All others plus unknown
Spasms	Present	Absent
Fever	>38.4^{0}C	<38.4^{0}C
Tachycardia	Adults >120 beats/min Neonates >150 beats/min	Adults <120 beats/min Neonates <150 beats/min
Total score		

A score of 0 -1 indicates mild illness with a mortality of up to 10%

A score of 2 – 3 indicates moderate illness with a mortality of up to 20%

A score of 4 indicates severe illness with a mortality of up to 40%

A score of 5 – 6 indicates very severe illness with up to 50% mortality

Table 2: Summary of complications

Body System	Complication
	Autonomic dysfunction
Airway	Aspiration, laryngospasm, airway obstruction
Respiratory	Hypoxia, apnoea, Type I and II respiratory failure, Acute respiratory distress syndrome (ARDS), complications of prolonged mechanical ventilation
Cardiovascular	Tachycardia, hypertension, ischaemia, hypotension, bradycardia, arrhythmias
Renal	Renal failure, stasis and urinary tract infection
Gastrointestinal	Stasis, ileus, haemorrhage
Miscellaneous	Weight loss, thromboembolism, sepsis, multi organ dysfunction syndrome, fractures due to spasms

MANAGEMENT

This must be done either in a neonatal intensive care unit or paediatric intensive care unit for the older child. These are however limited in most hospitals in the low-income countries contributing to the high mortalities reported.

The management aims to provide supportive care till the neurotoxin bound to the nervous tissue has been eliminated. This is done by:

- Neutralization of the circulating toxins
- Elimination of the source of the toxins
- Control of rigidity, spasms and management of complications

Neutralization of circulating toxins

As the damage caused by tetanospasmin that has entered the nervous tissue is irreversible, emphasis is placed on neutralizing the circulating toxins before it enters the nervous system. Human tetanus immune globulin is the preferred drug and is given at a dose of 150units.kg^{-1} intramuscularly. When unavailable, equine anti-tetanus serum at a dose of 500-1000units.kg^{-1} should be given intramuscularly or intravenously. The latter requires pretesting before administration. Antitoxin should be given as soon as diagnosis is made. Some authors have explored administering these immunoglobulins intrathecally. This has however been found to have no added benefit.

Elimination of the source of the toxins

The wound, if obvious, should be surgically debrided. Intravenous (IV) metronidazole (15mg.kg^{-1}stat then 7.5mgkg^{-1}every 8 hours for 10 days) is preferred to IV Penicillin G (100,000 – 200,000IU. kg-1day^{-1} IV in 2 divided doses). Penicillin G causes a non – competitive, voltage dependent inhibition of GABA receptors. With this, it can cause seizures and potentiate the action of tetanospasmin. Macrolides, clindamycin, and chloramphenicol are also effective alternatives. With neonatal tetanus, broad spectrum antibiotics such as the third generation cephalosporins are often added because the neonate usually presents with sepsis.

Control of rigidity and spasms

Benzodiazepines are the standard therapy for controlling muscle spasms in tetanus and have gained popularity over other agents due to their combined muscle relaxant, anticonvulsant, sedative and anxiolytic effects. Benzodiazepines modulate GABA transmission and increase pre-synaptic inhibition. The most popular is diazepam which is cheap and readily available in low income countries where tetanus is still a significant health problem. It is administered at a dose range of 0.1 – 10mg.kg^{-1} per dose. It has a large volume of distribution and may lead to prolonged recovery when the doses are tailed off. Midazolam, a short acting benzodiazepine compared to diazepam, is favored in critical care for sedation. It is theoretically a better option than diazepam for tetanus. There is however limited evidence of its use in the literature. Anticonvulsants such as phenobarbitone (5mg. kg^{-1} per day) and phenothiazines usually chlorpromazine (0.5mg.kg^{-1}) are often added as adjunctive sedatives to diazepam. Propofol may be used in adults with tetanus because of its excellent sedative effects and it does not accumulate. It is however avoided in neonates and children as a sedative because of untoward metabolic, cardiac and renal effects. In severe tetanus, spasms are often not controlled even with high doses of these agents and neuromuscular blockade will be required.

Endotracheal intubation with mechanical ventilation should be undertaken for all cases of severe tetanus. This should be done with rapid sequence induction using IV suxamethonium (2mg.kg^{-1}) as the child is prone to aspiration. This can be continued with intermediate muscle relaxants like IV atracurium (0.5mg.kg^{-1}) or vecuronium (0.1mg.kg^{-1}). Pancuronium (a long acting muscle relaxant) may worsen autonomic instability by inhibiting catecholamine reuptake so should be avoided. Prolonged usage of these amino steroid muscle relaxants has been associated with critical illness neuropathy and myopathy. Tracheostomy should be performed in patients requiring intubation for more than 5 days.

Intrathecal baclofen (a GABA-B receptor agonist) and dantrolene (a skeletal muscle relaxant) have been investigated but limited to a few case series and are not readily available in the resource-poor setting.

Control of autonomic dysfunction

Magnesium sulphate is an effective adjunct in relaxation, sedation, and controlling the autonomic disturbances in tetanus. It is a pre-synaptic neuromuscular blocker, reduces catecholamine release from nerves and the adrenal medulla and reduces receptor responsiveness

to released catecholamine. Its use has been well described in literature. It reduces the requirements of other sedatives and muscle relaxants in controlling rigidity and spasms. It is administered at a dose of 100 – 400mg.kg^{-1}hr^{-1} in children. In neonates a loading dose of 50mg.kg^{-1} followed by a maintenance dose of 30 – 50mg.kg-1hr^{-1} is given. By antagonizing calcium metabolism, magnesium causes weakness and paralysis in overdose. Monitoring of serum magnesium levels is important to prevent this. The normal serum magnesium level is 0.7 – 1.0mmoll^{-1}, while an acceptable therapeutic level is 2 – 3.5mmol^{-1}. This laboratory investigation may not be available in the resource poor setting thus limiting its use. Monitoring of the deep tendon reflexes, urinary output as well as respiratory rate in the spontaneously breathing child is imperative as a clinical index of toxicity. The use of invasive blood pressure monitoring, if available may facilitate early recognition of autonomic dysfunction with prompt interventions instituted.

Opioids like morphine and fentanyl have been used in the management of autonomic dysfunction. They induce peripheral arterial dilatation by reflex reduction in sympathetic α-adrenergic tone, through alteration of the sympathetic efferent discharge in the central nervous system.

Beta-blockers (particularly long-acting agents like labetalol) have been implicated in sudden cardiac death and are not recommended. The short acting beta-blocker, esmolol, may be used to manage tachycardia and hypertension, where invasive monitoring is available. It is also not readily available.

The alpha-2 agonists, clonidine and dexmetomidine, inhibit the release of norepinephrine from prejunctional nerve endings and may have a useful role.

Supportive care

This is crucial to the outcome of children admitted with tetanus. A multidisciplinary approach is essential. Poor nutrition with subsequent weight loss occurs rapidly because of dysphagia, altered gastrointestinal function and high metabolic rate. Enteral nutrition should be established early via nasogastric tube or percutaneous gastrostomy. Fluid and electrolyte imbalance should be corrected because of fever, diaphoresis and excessive secretions. Prevention of respiratory complications includes meticulous mouth care, chest physiotherapy and regular orotracheal or tracheostomy tube suctioning. Steps should be taken to prevent ventilator associated pneumonia. Nosocomial infections are common because of the prolonged course of the disease and remains a cause of mortality. Chest and limb physiotherapy may be limited in the early stages of the disease as it provokes spasms. Other supportive measures include prevention of venous thromboembolism, ulcers and pressure sores.

Late Sequelae of Tetanus

Tetanus has been associated with significant morbidity in children who survive. Microcephaly, mental retardation, motor disabilities and growth failure have been observed in children who recovered from neonatal tetanus. Transient or permanent disorders such as irritability, memory and sleep disorders, learning disabilities have also be reported in children who recovered from post-neonatal tetanus. In the latter group, electroencephalogram abnormalities were observed to be higher than in the normal population.

Prevention

A child that survives tetanus is still prone to tetanus in the future because the infection does not confer any immunity. Active immunization must be performed with Diphtheria Pertussis Tetanus (DPT) vaccine given at age 6weeks, 10weeks, 14weeks of life, 18months and 5years. Immunization of pregnant women and women in the reproductive age is essential. There should be prompt and adequate care of wounds with hygienic care of the umbilical cord in newborns. Children with tetanus prone wounds need to be reviewed to check if they will benefit from passive immunization.

Conclusion

Tetanus is a third world disease requiring first world facilities in its management. Primary prevention is key especially in the low-icome countries instead of management and rehabilitation of its sequelae.

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Clinical Review

Update in
Anaesthesia

Children with sickle cell disease: acute complications, acute pain and perioperative management

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Abstract

Sickle Cell Disease (SCD) is a haemoglobinopathy with multisystem complications. Anaesthetists are frequently involved in peri-operative management, managing acute complications, particularly those requiring critical care, and providing expertise in managing acute pain. Common acute complications are vaso-occlusive episodes including splenic complications, sepsis, acute chest syndrome and stroke, priorities in management of which are adequate oxygenation and hydration, blood transfusion to improve oxygen delivery and reduce the percentage of sickle-haemoglobin, and multimodal analgesia. In low and middle-income countries, children are most commonly seen by healthcare professionals when presenting acutely, therefore chronic management and risk reduction must also be considered at this point. Peri-operatively, priorities for care are optimisation of oxygen delivery and blood flow to the tissues including avoidance of hypoxaemia, hypercarbia, hypotension, hypothermia and acid-base disorders, ensuring adequate pain management, and promoting recovery. Care should be in settings with specialist expertise in SCD from paediatric, anaesthetic, surgical and critical care teams. Focus on development of systems for surgical care for SCD children in prevalent regions, including rapid access to blood products, developing experience in rural centres, referral pathways to regional specialist hubs, and local guideline and research development, is required to reduce the high childhood mortality from SCD seen globally.

Key words: Anaemia, Sickle Cell, Haemoglobin, Sickle, Perioperative period

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INTRODUCTION

Sickle Cell Disease (SCD) is an inherited structural disorder of haemoglobin when both β-globin chains present in adult haemoglobin (HbA) are abnormal, and at least one is the sickle defect when a valine is substituted for a glutamic acid at codon 6 on chromosome 11.[1] This causes the chain to become more hydrophobic and polymerise in hypoxic environments[1], causing "sickle" shaped red blood cells (RBCs). Sickle cell anaemia (SCA) is the homozygous HbSS variant and occurs when the sickle codon defect is inherited from both parents, therefore both β-globin chains have this tendency to polymerise. Other forms of SCD, where one globin inherited is sickle and the other is of a different haemoglobinopathy, include HbSß-thalassaemia and HbSC. Inheriting one sickle cell and one normal β-globin gene leads to Sickle Cell Trait (SCT), in which haemoglobin tends to polymerise only in extreme physiological circumstances, for example of relevance peri-operatively, when on cardiac bypass.

β-globin chain production, required for HbA, starts at approximately four-six months of age and gradually increases becoming the predominant haemoglobin type in adulthood. Until this point, HbF is the predominant haemoglobin, which does not require β-globin chains. As such, children are unlikely to show consequences of SCD before this age.

When β-globin chain polymerisation occurs, RBC sickling results causing micro-circulation occlusion and subsequent ischaemia.[1] In addition, there is growing evidence of other vascular and inflammatory pathologies also leading to micro-occlusion, including abnormalities of endothelium promoting cellular adhesion[2], and platelet derived inflammatory cytokines.[3] Sickle RBCs are also prone to lysis[4] causing haemolytic anaemia.

SCD is most prevalent in Sub-Saharan Africa, in a similar distribution pattern to malaria[5] because SCT and some forms of SCD offer protection against Plasmodium falciparum infection[5], conferring potential survival benefits. Conversely, patients who have SCA are more likely to develop life-threatening malaria, and consequently mortality secondary to malaria is higher.[6]

85% of children with SCD are born in Africa[5], with most of the remainder born in parts of Asia, the Caribbean, Central and South America and the Mediterranean.[7] Less than 1% of cases globally are in North America and Europe[7], however most published research into SCD management is from these regions.

There is a great disparity globally between the prevalence of SCD among children and the availability of resources and systems for optimal management, where common challenges include:

- lack of access to diagnostics, including neonatal screening, thus diagnoses are made after acute complications start in childhood and a presumptive diagnosis when laboratory investigations are unavailable
- children, especially those living rurally, lacking access to a centre with specialist expertise in SCD and effective optimisation, reducing acute and chronic consequences
- lack of access to treatments that reduce the incidence of complications (namely immunisations and hydroxyurea)
- lack of blood products to treat acute presentations and to optimise children peri-operatively
- lack of availability of analgesics

As a result of these challenges to care, childhood mortality (in particular under-5 mortality), from SCD remains high in many African countries[8], most commonly from bacterial sepsis or severe anaemia.[7]

There is limited usefulness in directly transferring practices and research from high-income contexts to contexts facing these challenges.[7] In order to meet the needs of children living in these areas, we need to share expertise internationally looking for practical measures that can be taken to improve care, and strategies for local research and guideline development.

DIAGNOSIS AND SUBSEQUENT MANAGEMENT

Newborn screening for SCD is an effective method of early diagnosis enabling parental education and interventions aimed at reducing morbidity and mortality, before the onset of acute complications. Following successful results from fully-implemented screening programmes[9], some sub-Saharan African countries are operating partial screening.[10] Globally however, screening remains rare, therefore diagnosis commonly happens when a child presents acutely[11] after the fall of fetal haemoglobin (HbF). Example of methods of diagnosis are described in table one.

It is important to recognise challenges in diagnosing other forms of SCD, for example HbSC. As crises in these patients are often less frequent and severe, patients may not present acutely. Therefore, if they present for surgery not yet diagnosed, there is potentially a greater risk of a crisis occurring peri-operatively.

A study in a prevalent region of Kenya suggested an algorithm for identifying children for SCD testing where presentation with one of: clinical jaundice, severe anaemia, bone or joint infection, or stroke, had a high yield of positive results, representing an efficacious stratified screening technique.[11] In contexts where testing is unavailable, our personal experience is that a child presenting with two of a history of recurrent abdominal pain, bone pain, and jaundice should direct the clinician to a diagnosis of SCD.

Once diagnosed, children with SCD should remain under the care of a clinician with expertise in the field, commonly a paediatrician with a special interest or haematologist, enabling optimisation of the chronic disorder (table two) and subsequently, reduction of acute complications, development of end-organ damage and mortality[1].

Regarding hydroxyurea, positive outcomes have been shown in children with HbSS or HbSβ0 including a significant decrease in adverse events[13], resulting in many countries routinely offering hydroxyurea to children with SCA and some other forms of SCD. Myelosuppression is a complication, most commonly neutropaenia[13], and therefore follow-up and monitoring are essential.

There are few published studies specifically assessing outcomes of hydroxyurea in sub-Saharan Africa, important as the pattern of co-morbidities among children, including infections, malnutrition and challenges associated with drug adherence and follow-up, are different to the contexts that have been studied the most.

One available study across multiple centres in sub-Saharan Africa demonstrated benefits of hydroxyurea[4] including significant increase in total haemoglobin and HbF levels, and reduction of all SCD-related adverse and serious events including vaso-occlusive episodes (VOE), non-malaria infection, malaria infection, transfusions and death. Importantly this study demonstrated excellent adherence rates to treatment[4], however the drug was donated to the study and therefore access was not limited by procurement challenges and cost. In this study, the drug had an excellent safety profile[4], but the systems for follow-up and drug monitoring are difficult to replicate everywhere.

ACUTE COMPLICATIONS

The most common acute complications are infection[11], VOEs[11], acute chest syndrome (ACS)[11,14] and stroke.[11,15] VOEs most commonly presents with pain in the long bones, back, chest and abdomen. Vaso-occlusion is treated supportively aiming to improve blood flow and oxygen delivery to affected tissues. Treatment involves oxygen and intravenous fluid therapy, being mindful that as children may present very anaemic, it is important to ensure they are not overloaded with crystalloid and instead are transfused when needed. Early multimodal analgesia (discussed in Acute Pain Management section) is essential for patient comfort and reducing sympathetic drive which may worsen ischaemic symptoms. Children presenting rurally who do not improve with these simple measures should be referred to a tertiary centre with SCD expertise.

ACS is most common in young children[1], carries a high rate of mortality and morbidity and recurrent episodes can cause chronic cardio-respiratory complications.[14] ACS is defined as "fever and/or

Table 1: Common diagnostic techniques for SCD

Test	Method	Advantages	Disadvantages
Solubility testing	Blood sample is mixed with a buffer and centrifuged. Sickle haemoglobin is identified by an insoluble red layer on top of a yellow liquid	• Widely available test • Sensitive	• A mixed result can occur in SCT, the presence of HbF, or following a transfusion • Unable to differentiate between SCA and other forms of SCD, or give a quantitative measure of HbS
Peripheral blood film	Blood sample is observed under a light microscope for sickle-shaped RBCs	• Widely available test	• Unable to detect SCT • Unable to differentiate between SCA and other forms of SCD, or give a quantitative measure of HbS
Sickling test	As for the peripheral blood film, however sample is exposed to a hypoxic environment to encourage sickling first	• Widely available test • More likely to detect SCT than peripheral blood film	• Unable to differentiate between SCA and other forms of SCD or give a quantitative measure of HbS
Hb- electrophoresis	Haemoglobins separate based on their difference in charge in an electric field, and are identified as different bands[12]	• Can discriminate between the type of SCD by the haemoglobin present • Can quantify the percentages of abnormal haemoglobin and HbF present	• Higher cost than above methods, however is likely the cheapest diagnostic test that can differentiate SCD type • Labour intensive and time-consuming
Isoelectric focusing	Haemoglobins separate according to their charge using a pH gradient and gel medium[12]	• Can discriminate the type and quantify as for Hb-electrophoresis, however quantification is more precise[12]	• Expensive • Labour intensive and time-consuming
High-performance liquid chromatography	Haemoglobins are displaced from a negatively charged column by a positively charged solution at a rate which is displayed graphically giving haemoglobin present and the quantity[12]	• Precise quantification of haemoglobin present[12] • Rapid automated technique capable of handling many samples per day[12]	• Expensive • Higher technical expertise needed • Regular calibration required

respiratory symptoms with new pulmonary infiltrate on chest x-ray".[16] It occurs when a precipitant causes an area of poor ventilation in the lung (commonly infection), which initiates a downstream response of molecular interactions resulting in vaso-occlusion. Sickling, endothelial dysfunction, platelet activation, activation of the clotting cascade, and a relative loss of nitric oxide, all playing a role[14]. A spiral of worsening ventilation, perfusion and mismatching occurs, and the child can deteriorate rapidly. A study in Nigeria showed a high proportion of hypoxaemia in children with SCA presenting acutely with a VOE[17], highlighting that all children with SCD who are acutely unwell, are high-risk for ACS. This is important peri-operatively as acute surgical illness, pain and atelectasis, (common after anaesthesia or an acute abdomen), are all risk factors. Presenting signs and symptoms include fever, cough, wheeze[16] and signs of increased work of breathing. Predictors of severity include worsening hypoxia (therefore continuous pulse oximetry is essential), increasing respiratory rate, work of breathing, and signs of shock. Broad-spectrum intravenous antibiotics with atypical cover are given and children should also receive a blood transfusion aiming for haemoglobin of 10g dl^{-1}, which often rapidly improves hypoxaemia and reduces the percentage of circulating HbS[16] stopping the spiral of clinical deterioration. Adequate pain management to enable comfortable breathing and reduce further atelectasis is important, and should be carefully titrated in a monitored environment to avoid

Table 2: Interventions known to reduce acute complications of SCD, including SCA, and progression to chronic complications

	Interventions	Rationale
Immunisation	• Routine childhood vaccinations • Additional vaccines for Streptococcus pneumoniae, Haemophilus influenzae (Hib) and Neisseria meningitidis (Men C)	Children with SCD are at an increased risk of many infections, particularly from bacterial encapsulated organisms secondary to functional asplenia
Prophylactic antibiotics	• Oral penicillin prophylaxis is commonly used up to age five years	
Malaria risk reduction	• Parental education, including use of mosquito nets • Assessment for the need for antimalarial chemoprophylaxis (based on prevalence, seasonal variation, local resistance, children with SCA or a history of previous severe malaria)	Children, particularly those with SCA, are at a high-risk of severe- and life-threatening malaria
Nutrition	• Parental education, folate replacement and micronutrient supplementation	Good nutrition reduces loss from rapid cell turnover and haemolysis
Pharmacological prolongation of HbF production	• Daily oral hydroxyurea	Hydroxyurea continues HbF production after the age at which it normally ceases, resulting in a lower percentage of HbS present

further complications. Bronchodilators are used to treat wheezing which may suggest bronchial hyperreactivity is a component in the pathogenesis.[14] Children should be managed in an intensive care setting, and when presenting to an institution without these facilities should be resuscitated with the above measures, and referred onwards when safe.

Splenic sequestration is a rapid enlargement of the spleen which sequesters blood, occurring commonly in infants and leads to hypovolaemic shock. Treatment is also supportive using blood products, therefore access is essential, and when an infant presents with this complication, measures to ensure blood availability should be arranged early.

Ischaemic stroke is a common cause of morbidity and mortality occurring in children with SCD globally[1]. However, a study of paediatric admissions in a prevalent region in Kenya, reported that stroke was less prevalent in this context than reported in high-income settings, perhaps reflecting that fewer children with SCA survive to the ages at which stroke increases in prevalence[11]. Stroke occurs as a result of sickle-shaped RBCs and the turbulent blood flow at sites of bifurcation in the anterior and middle cerebral arteries[18]. Venous occlusion and haemorrhagic stroke also occur. Children presenting with acute ischaemic stroke are treated supportively maintaining oxygen saturations >95%, and transfusion to reduce the percentage of HbS, in addition to exchange transfusion where available.[19]

Transcranial Doppler Ultrasonography (TDU) has been piloted in the context of stroke risk assessment in SCD in some prevalent regions[18], however this screening tool is not yet commonly used in sub-Saharan Africa, and if implemented its success requires a multidisciplinary specialist-led pathway and access to regular transfusion.

ACUTE PAIN MANAGEMENT

In regions where SCD is prevalent, difficulty accessing preventative medication, specialist outpatient care and centres with expertise in SCD are high, increasing the incidence of acute presentations. Prompt, effective treatment of pain during these episodes is essential and whilst concurrently treating the underlying complications, administration of first analgesia should occur within 30 minutes of presentation. Although often difficult to achieve, this can be helped by training staff to triage children with SCD as they present, for urgent clinician review.[20]

Arguably, the two most significant challenges to providing optimal analgesic management in low and middle-income countries are a disproportionate lack of access of analgesic agents, most notably opioids[21,22], and a widespread culture of concern over the potential adverse effects of opioids, resulting in less prescribing and administration in patients with acute severe pain.

When a child presents with acute pain, simple analgesic measures including regular paracetamol and Non-Steroidal Anti-Inflammatory Drugs (NSAIDs) should be given and repeated at regular intervals. Despite poor availability at many centres, oral morphine remains the mainstay of treatment, recommended for moderate or severe pain (or for mild pain not responding to simple measures) at a dose of 0.2-0.4mg.kg^{-1} and repeated as necessary. If appropriate monitoring is available, intravenous morphine (0.1-0.2mg.kg^{-1}) may be appropriate for children in severe pain, converting to oral morphine once controlled. Over-sedation and hypoventilation associated with opioids can worsen an acute sickle cell presentation by leading to hypoxia and hypercarbia, therefore children must be cared for in an environment able to assess for these, including the use of sedation

scores. Opioids should not be avoided due to this fear however, as poorly treated pain can also result in deterioration and long-term complications. Ketamine has an important role in analgesia here particularly due to it being a non-scheduled drug internationally and therefore not under the same legislation that often challenges widespread use of opiates[22], and it has a good safety profile at analgesic doses.

Assessment of pain is best achieved using paediatric pain scales including self-reporting in older children, for example using the FACES scale, or using behavioural observation scales in younger children and infants.[23] However, knowledge of these tools is often not widespread and explanation can be lost between language translations, therefore locally developed tools in regular use by staff would be advantageous.

PERIOPERATIVE MANAGEMENT

The most commonly performed surgery for children with SCD in endemic regions is splenectomy. Indications include more than two episodes of splenic sequestration, and, occurring in older children, hypersplenism, where haematological manifestations including pancytopaenia are likely. Cholecystectomy and sequestrectomy in chronic osteomyelitis are also common. Children may also present for surgery unrelated to SCD, for example appendicectomy and hernia repair. Similar to acute presentations, the most common post-operative complications are VOEs, ACS[15] and post-operative sepsis. Peri-operative stroke can also occur.[15]

The perioperative management of children with SCD centres around pre-operative optimisation and ensuring children have adequate oxygenation, hydration, and pain control, together reducing risk of complications. Excellent multidisciplinary teamwork ensuring communication, planning and handovers between all involved medical and nursing specialties, is essential. An experienced anaesthetist and surgeon should be present, the latter enabling the shortest possible operating time and use of minimally-invasive techniques where possible. Laparoscopic surgery is widely considered advantageous in this patient group[24] however is not commonly used in paediatrics across institutions where children with SCD most commonly present. While this develops, other measures to reduce post-operative pain and increase recovery should be prioritised.

PRE-OPERATIVE

Surgery should be undertaken at a centre best equipped with the resources and specialists to care for children with SCD, including critical care facilities on site. Day surgery is not recommended. Multi-specialty planning and optimisation of the child should happen as early as possible. In the case of emergency surgery, where less time for optimisation may be available, theatre team briefings and discussion with paediatrics and critical care remain essential.

Pre-operative assessment should assess for acute and chronic complications of SCD, being mindful of the high incidence of concurrent ACS, VOE and hypoxaemia among children with SCD presenting with acute surgical complications. Current haemoglobin concentration should be checked. The percentage of circulating HbS should be checked, and if not available, treated as if this is high.[25]

Children with other acute or chronic complications may require further investigations for example chest x-ray, spirometry or echocardiography if available. Where available, all children should have TDU assessment assessing stroke risk within the last 12 months.[25] Blood should be cross-matched except for minor surface procedures, and if systems for accessing blood quickly are not available, this should be in the operating theatre prior to the start of surgery.

Fluid status must be optimised pre-operatively and steps taken to reduce the risk of dehydration including ensuring that children with SCD are first on the list wherever possible.

The Transfusion Alternatives Preoperatively in Sickle Cell Disease (TAPS) study[26], reported a significant reduction in perioperative complications including ACS and requirement for post-operative transfusion, when children with either HbSS or HbSβ0 Thalassaemia undergoing low/medium risk elective surgery received a transfusion of packed red cells up to a haemoglobin concentration of 10g dl-1 if their presenting haemoglobin was <9g dl^{-1}, or, if higher, an exchange transfusion to an estimated HbS percentage of <60%. It is now recommended to transfuse all children with SCD undergoing surgery to these guidelines, and furthermore in the case of high-risk children or children undergoing high-risk surgery, also aim for a pre-operative HbS <30%.[25]

INTRA-OPERATIVE

Intra-operatively, avoiding hypoxaemia, dehydration, acidosis and ensuring normocarbia and normotension is essential. Avoiding heat losses is also important to avoid vasoconstriction and increased blood viscosity that can result, and lead to increased tendency towards vaso-occlusion.

Adequate analgesia is essential intra-operatively for reducing the stress response secondary to acute pain and ensuring post-operative adequate ventilation, good mobilisation and recovery. Regional anaesthesia is advantageous here by providing effective pain relief and reducing the requirement for opioids and associated side effects, most concerning hypoventilation, but also constipation and nausea which can complicate recovery. The surgical team can also infiltrate local anaesthetic in an appropriate surgical plane under direct vision, for example in the rectus sheath, transversus abdominis plane or inguinal canal. Antiemetics should be given and other strategies taken, including avoidance of gastric insufflation, to reduce risk of post-operative nausea and vomiting, subsequently avoiding further fluid losses and delayed recovery.

Intra-operative limb tourniquets carry a risk of local hypoxia and acidosis distal to the tourniquet increasing the risk of vaso-occlusion both in the operative limb, and elsewhere after release. The use of a tourniquet is a patient-specific team decision where the risk of increased blood loss and length of surgery without its use needs to be weighed against the potential increased risk of a sickle-related complication. If used, volume status and oxygenation should be optimised before application of the tourniquet, and lower tourniquet pressures considered.

Extracorporeal circuits confer additional risk of sickling due to a hypoxic environment. In the case of cardiac surgery on-bypass, children are optimised pre-operatively as for high-risk surgery with transfusion and exchange transfusion, and hypothermia on bypass avoided. For this reason, cell salvage is also contraindicated.

POST-OPERATIVE

The same goals for adequate oxygenation, hydration and pain control are required post-operatively. Children undergoing high-risk surgery, or high-risk children including those with a history of ACS or chronic cardio-respiratory comorbidities, should be cared for in an Intensive Care Unit with paediatric experience.

CONCLUSION

Recurrent themes in discussing management of children with SCD are the need for appropriate systems of care, staff with appropriate expertise, and resources available for diagnosis, management of acute exacerbations and long-term optimisation. Understandably, children living in areas with the greatest prevalence, particularly those most rural, disproportionately lack access to these systems. While these systems are being developed, it is important that all staff working where these children may present have knowledge on SCD, including acute complications and perioperative and acute pain management, which is kept up-to-date with continuous medical education. In addition, identifying children who need referral on, and developing regional hubs to care for these children is essential. This combination of improved knowledge and experience in rural areas, access to regional specialist expertise, and excellent communication between the two is likely to be the best strategy for developing care and reducing global childhood mortality from SCD.

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Update in
Anaesthesia

Anaesthesia for neonatal and infant male circumcision

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Abstract

Male circumcision is the commonest surgical procedure performed worldwide. It is mostly performed in the neonatal and infantile period as a daycase procedure. Analgesia is essential as it prevents development of long term deleterious effects. Non-pharmacological methods of analgesia mainly provide comfort. Adequate analgesia is provided by regional techniques or general anaesthesia. Post-circumcision bleeding is the most common complication encountered.

Key words: circumcision; male; neonate; infant; anaesthesia technique

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INTRODUCTION

Male Circumcision is the surgical removal of the prepuce or foreskin which covers the tip of the penis. It is one of the oldest and most common surgical procedures performed worldwide. Circumcision is commoner in certain parts of the world, including Nigeria where it is traditionally performed in the newborn period. However it can be delayed into the infantile period.

The prevalence of male infant circumcision is as high as 80% in West Africa, Middle East and North Africa. On the other hand prevalence of 20 % is documented for Europe, Asia and Latin America.[1] In one tertiary health institution in Nigeria, 15-20 newborn circumcision were performed weekly. The actual incidence is more as a large number of circumcisions are performed outside the tertiary health institutions.

Most males are circumcised for religious, or cultural reasons, other reasons may be parental personal preference, for personal hygiene and preventive health care.

Male circumcision is performed by a range of providers; medically trained (nurses, medical officers, surgeons, paediatricians) and non-medically trained (traditionalists, religious leaders, and community health workers). This article will focus on medical circumcision only.

The American Urological Assosciation (AUA) believes that neonatal circumcision has potential medical benefits as well as risks. They list the various health benefits as[2]:

- Decreased incidence of penile cancer
- Prevention of penile problems; phimosis, paraphimosis, balanitis, posthitis
- Decreased risk of acquisition and transmission of sexually transmitted infections; HIV, HPV, herpes simplex virus, trichomonas vaginalis
- Decreased risk of urinary tract infection in infancy
- Easier penile hygiene.

Risks associated with circumcision include bleeding, infection and penile injury in the immediate period, as well as buried penis, meatal stenosis, skin bridges, chordee and poor cosmetic appearance that may occur later[2].

Nerve supply to the penis

The penis is supplied by nerves originating from sacral roots S2, S3 and S4 (pudendal nerve), L1 (ilio-inguinal nerve) and L1-L2 (genitofemoral nerve). As the pudendal nerve exits the pudendal canal, it divides into the dorsal nerve of penis (DNP) and the perineal nerve. The left and right dorsal nerves of penis are the terminal branches of the pudendal nerve and innervate the distal 2/3 of the penile shaft while the perineal nerve supplies the underside of penis as well as the scrotum, base of glans and the anterior part of the perineum. During its course the DNP runs closely with the dorsal arteries of the penis and gives off small branches which supply the dorsal skin of the penis and the glans where it terminates.

After emerging from under the pubic bones, the DNP and their branches are enclosed in a fat-filled subpubic space which is divided in the midline by the suspensory ligaments resulting in two separate compartments.[3,4] This is the site of blocking the nerves. The 2 separate compartments necessitates injection of the local anaesthetic agent at these 2 different sites; the 10 and 2 o'clock positions.[5]

The ilio-inguinal and genitofemoral nerves supply the proximal 1/3 of the penile shaft. The genital nerve travels within the spermatic cord to supply the cremaster muscle, skin over the scrotum and adjacent thigh.[6]

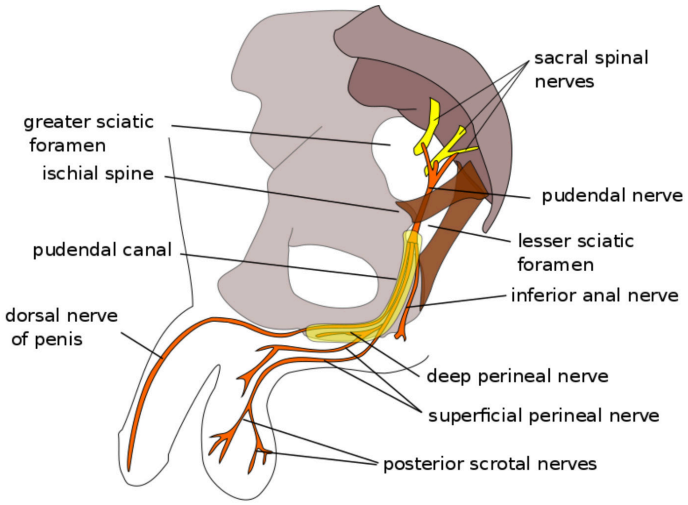

Figure 1: Nerve supply to the penis. Haggstrom, Mikael (2014). "Medical gallery of Mikael haggstrom 2014". WikiJournal of Medicine 1 (2). DOI:10.15347/wjm/2014.008.ISSN 2002-4436. Public Domain.

Tecniques of circumcision[7]

- *Clamping* – A clamp is placed over the glans after the foreskin has been retracted and preputial adhesions separated. The foreskin is replaced over the bell and the clamp assembled and closed, crushing the skin between. The distal prepuce is then excised without the need for sutures. There is a small risk of partial amputation of the glans if the device is not properly placed. Examples are Mogen clamp and Gomco clamp.
- *Plastibell* – A bell shaped plastic shield is placed over the glans to protect it and a ligature is tied across the bell and foreskin. The foreskin is then amputated. The ligature application prevents bleeding and produces ischaemic necrosis of the foreskin. There is usually no need for suturing with this method. The main disadvantage is that the shield must remain in place for several days before the skin separates thus may result in ring retention.
- *Dorsal slit* – The inner and outer preputial layers are crushed and divided by a dorsal slit made and extended to the corona. The prepuce is then freed and excised under direct vision.
- *Sleeve technique* – The outer layer then the inner layer of the prepuce are excised under direct vision. This technique is usually performed in infants and older children.

Anaesthetic considerations

Historically there had been much controversy about whether analgesia or anaesthesia is needed for circumcision in the newborn. Most practitioners believed and still do that the newborn does not feel pain and therefore the procedure can be done without any form of analgesia. The newborn is usually strapped to a restraint or held down by a nurse or the mother and the procedure performed, thereafter he is consoled with feeding. Recent knowledge attests to the fact that neonates do feel pain and inadequate pain management has deleterious effects on them in the immediate and long-term period.[8]

A balance therefore has to be struck between providing anaesthesia/analgesia for these infants and neonates and the availability of experienced skilled personnel as well as appropriate equipment to do so safely.

Pre-operatively the child must be physically well with no active respiratory infection. A good history should eliminate cardiac, respiratory or bleeding disorders. The presence of any of these should delay the procedure for more extensive pre-operative assessment and optimization.

It is generally accepted that preterm babies <37 completed weeks, ex-premature babies with a post-conception age of <60 weeks and babies weighing less than 2.5kg should not undergo daycase circumcision under general anaesthesia because of the fear of post-operative apnoea.

Male circumcision should not be performed until at least 12 to 24 hours after birth. This gives time for the neonate to be stable after birth and an assessment to be performed on him.[9,10]

Neonatal circumcision is an elective procedure therefore it should be postponed if penile and genital anomalies exist. Since the foreskin is often needed to correct abnormalities, its removal may preclude or reduce the available options for subsequent surgical corrections. In addition, the complication rates are higher where these abnormalities exist.[11,12]

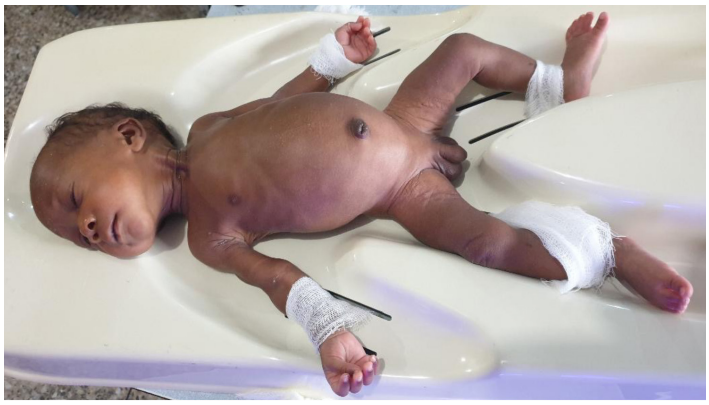

Figure 2: - A neonate in a restraint.

Pain control in neonatal circumcision

Circumcision is exclusively done as an elective out-patient basis except in conditions mentioned above and analgesia chosen should extend into the post-operative period for effectiveness. Newborn

Table 1: Anatomic abnormalities of the penis requiring postponement of circumcision[11,12]

	Type of fluid	Volume of fluid
Primary penile abnormalities		• Hypospadias • Epispadias • Chordee without hypospadias • Micropenis
Dartos Fascia Abnormalities	• Buried penis • Penoscrotal transportation • Penile torsion	
Ambiguous Genitalia		
Penoscrotal anomalies and distortion	• Penoscrotal webbing • Significant hydroceles and hernias	

babies respond appropriately to painful stimuli such as clamping or cutting of the foreskin during circumcision. Circumcision without any form of analgesia causes severe pain and distress, plethora, mild cyanosis from prolonged crying, respiratory pauses and regurgitation of feeds. Thus, it is very important that all medical practitioners who perform circumcision to do so after administering appropriate anaesthesia or analgesia.

If untreated, the pain of circumcision can result in both short and long term changes in infant behavior as they may develop excessive pain tolerance and hyperalgesia later in life. Injury and tissue damage sustained in infancy modulates the pain response even after the wound has healed as demonstrated by a greater pain response to routine vaccinations at 4 and 6 months in male infants who had been circumcised without analgesia compared to those who received EMLA application.[8]

As neonates & infants are not able to communicate verbally, physiological and behavioural responses to pain thereby gain more importance in the assessment of pain in them. These include

- Decreased oxygen saturation levels
- Increased heart rate and respiratory rate
- Increased duration and intensity of crying

There are also known specific neonatal pain assessment tools like Neonatal Infant Pain Scale (NIPS) and Premature infant pain profile (PIPPS) that can be employed.[13]

ANAESTHETIC TECHNIQUES

General anaesthesia for neonates is fraught with risks which include development of post-operative apnoea, difficult intubation especially in untrained hands, laryngospasm and bradycardia with airway instrumentation. These real problems limit the administration of general anaesthesia to skilled personnel in well – equipped centres.

Circumcision worldwide is performed by numerous skilled as well as unskilled personnel and this has necessitated the considerations of and advocacy for other options to general anaesthesia. When analgesia or a local anaesthetic technique is used, the neonate ought to be monitored with at least a precordial stethoscope and a pulse oximeter. During general anaesthesia, standard monitoring as for any other procedure must be used. In addition, resuscitation equipment and drugs should be readily available.

Analgesic techniques to relieve pain during neonatal circumcision can be achieved by the use of non – pharmacologic and pharmacologic interventions.

Non-pharmacological interventions include:

- Swaddling
- Dimming the ambient light
- Sensorial Saturation- This is the use of positive stimuli like auditory, visual, tactile and gustatory to distract the baby's attention and reduce or nullify the painful stimulus. It is theorized that these various peripheral sensations saturate the central receptors and through the 'gate control system' excludes the painful stimuli[14]. It can be performed by the parents and provides a form of participation for them.
- Some authorities have suggested that feeding and belching prior to the procedure as well as maintaining a warm room temperature (ideally 72°F) are important measures to be taken to improve the neonates comfort during the procedure.[15]

Pharmacological Interventions to reduce the pain of circumcision include:

Acetaminophen

Acetaminophen is usually given orally at a loading dose of 20mg.kg-1or rectally at a loading dose of 30mg.kg^{-1} one hour before the procedure in neonates >32 weeks. In preterm neonates <32 weeks the rectal loading dose is 20mg.kg^{-1}.[16] Intravenous administration of 7.5mg.kg^{-1} if < 10kg just before the start of the circumcision can also be employed.[17] It is effective, safe and easy to administer. While oral absorption is reliable, the rectal route provides slow incomplete absorption except in neonates. Acetaminophen is also continued into the post-operative period orally.

Sucrose

Sucrose may be used to supplement the analgesia provided by local anaesthesia and acetaminophen. It is administered as a 2ml solution of either 12.5%, 25% or 50% on a pacifier or gauze. It is most effective when administered approximately 2 minutes before the procedure.[3]

The mechanism of action of sucrose is believed to be through stimulating an increase in endorphin production as well as the calming effect of suckling on the pacifier. Sucrose has however not been proven to be effective as a sole analgesic agent for relief of pain during circumcision.[3,18]

Local anaesthesia for neonatal and infant circumcision can be provided by the following techniques:

Topical Anaesthesia

Eutectic mixture of local anaesthesia (EMLA), a combination of 2.5% lidocaine and 2.5% prilocaine is often employed at a dose range of up to 1g. It is applied to the inner and outer preputial skin under occlusive dressing for at least 60 - 90 minutes before surgery. It is easy to apply with no needle pricks but the time to effective analgesia needs to be considered for efficient scheduling of procedure. With EMLA, there is the added risk of methemoglobinaemia due to absorption of the prilocaine. This may be of particular concern in neonates because of reduced cytochrome b5 reductase enzyme which is responsible for the reduction of methaemoglobin as well as their high level of foetal haemoglobin which readily oxidizes to the ferric state.[3,19] They may thus present with central and peripheral cyanosis. Minor side effects that could occur with EMLA include transient blanching and redness. EMLA application blocks cutaneous nerves only and may require additional analgesia/ anaesthesia for optimal effect especially into the post-operative period.

4% Amethocaine gel is an alternative with a faster onset of action of 30-45 minutes but is only licenced for term infants >1 month of age.[14] 4% topical lidocaine cream has also been employed.

Regional techniques[5,20]

The ideal regional analgesia technique for circumcision should have a high success rate, be easy to perform, with a short learning curve and a low risk of complications. The following techniques are applicable for circumcision, each with its merits and demrits

- **Dorsal nerve block of the penis (DPNB)** involves administration of local anaesthetic agent into the subcutaneous tissue at the root of the penis at the 10 and 2 o'çlock positions (some authorities advocate the 11 and 1 o'clock positions).[15]

It is highly effective and easy to perform. Drawbacks include haematoma formation (5%), a failure rate of 4-8% and prolonged learning curve.[21] With the patient supine a small gauge needle (25-27G) is inserted over the middle of the pubic arch at the base of the penis and angulated at 30-45° until it contacts the pubic symphysis. The needle is then withdrawn slightly and redirected to pass below the symphysis to the left or right of the midline to a depth that spans 2/3rd of the needle length (0.5cm). Prior application of a topical anaesthetic agent like EMLA helps to minimize needle pain. The anaesthetic is deposited at the 10 and 2 0'clock positions after negative aspiration for blood and without retracting the needle. Alternatively two separate injections can be made. A 2 - 3 minute period is needed for the anaesthetic to take effect. The use of an ultra sound may aid nerve location.

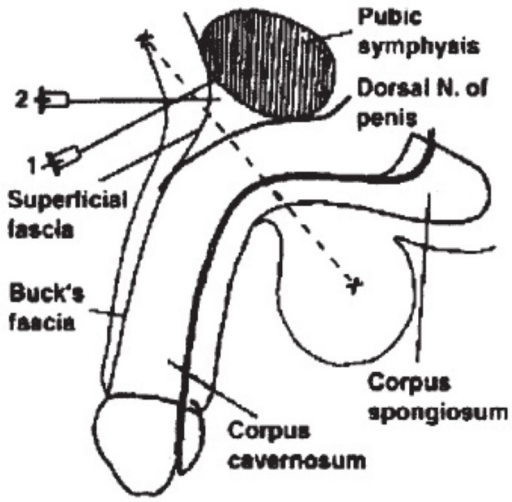

Figure 2: Anatomic abnormalities of the Penis requiring postponement of Circumcision[11,12]

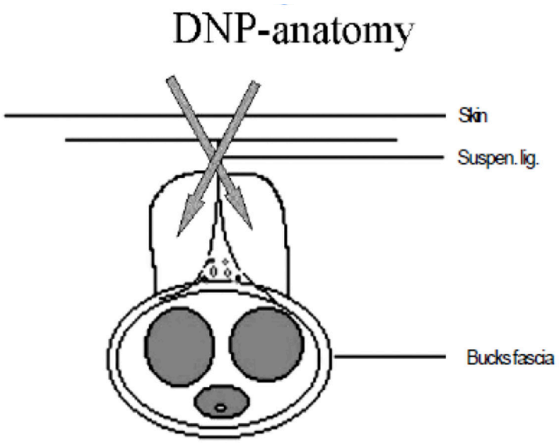

Figure 3: Direction of needle placement for DNBP

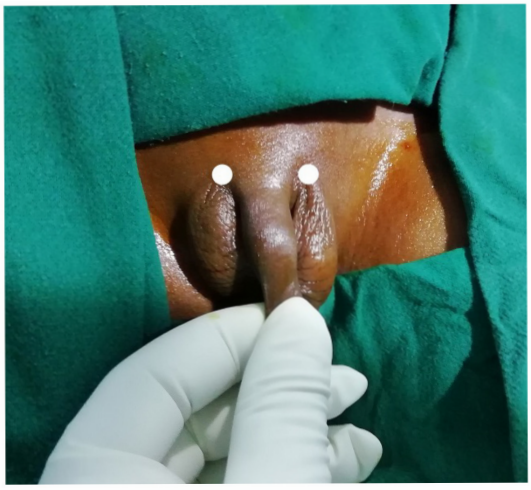

Figure 4: Injection at 10 and 2 o'clock positions for DNBP

1% plain lidocaine (xylocaine) or a 50:50 mixture of 1% plain lidocaine and 0.25% plain bupivacaine allows for provision of post-operative analgesia. All local anaesthetic agents must be devoid of epinerphrine because of its vasoconstrictive effect. The penis is supplied by end-arteries without collaterals and use of vasoconstrictors can lead to glans de-vascularisation. A volume of <1ml is required in neonates and 1-3mls in infants.[3] The maximum safe dose of lidocaine without adrenaline is 3mg/kg and of bupivacaine is 2mg/kg.

- **Ring block** involves subcutaneous circumferential injection of local anaesthetic agent around the base of the penis. It is easy to perform and does not require special skills. There is however a risk of injury to the urethra with injection on the ventral surface as well as inadvertent intravascular injection with injection on the dorsal surface of the penis. A negative aspiration test for blood must be ensured before injection.

The same local anaesthetic agents used for the DPNB is used for Ring block. In neonates, a volume of 1ml is sufficient while in infants 2 – 3ml may be required for adequate block.[3]

Inadvertent injection into Buck's fascia can lead to compression of the blood supply through the dorsal penile arteries and subsequent ischaemia of the glans.

- A Cochrane systematic review on pain relief for neonatal circumcision found DPNB to be the most effective for circumcision pain.[22] Some authors have however documented that ring blocks are more effective compared to DPNB.[23,24] There is thus no consensus on the most effective pain management for neonatal circumcision, A multimodal approach comprising topical+ regional anaesthesia + sucrose should always be considered.
- Caudal anaesthesia involves injection of local anaesthesia agents into the caudal space to block the sacral nerve routes. It produces very effective intra and post-operative analgesia but however requires appropriate skill and experience. A caudal block is usually performed after institution of a general anaesthetic in infants. The use of caudal blocks in the age group term to 6 months is associated with the highest incidence of complications.[25] Although the risk for systemic toxicity has been reduced following clear dosing guidelines, it can still occur therefore 20% lipid emulsion should be readily available.
- A caudal block may however be done awake in ex-premature babies.

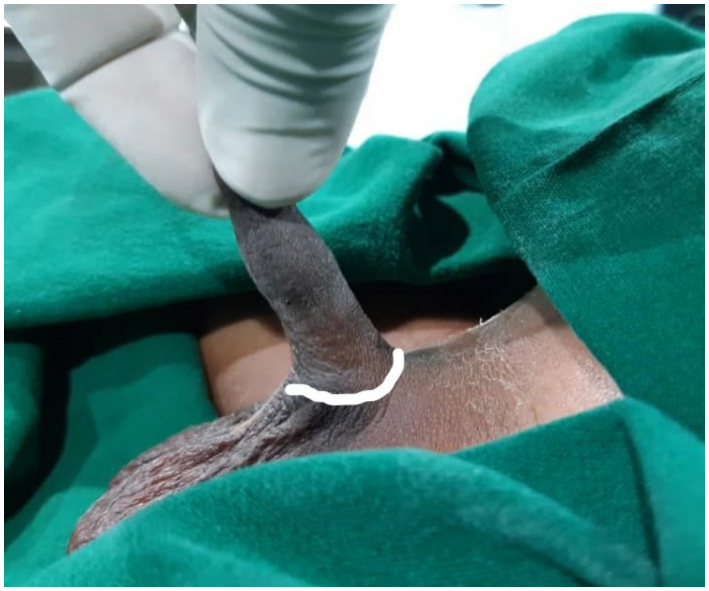

Figure 5: Circumferential injection of local anaesthetic agent around the base of the penis for Ring Block

A volume of 0.5mls/kg is sufficient for circumcisions. A dense block may be complicated by urinary retention which may prolong hospital stay. Usually 0.125% - 0.25% of plain bupivacaine or levobupivacaine or 0.2% ropivacaine is used. Additives may be employed to provide post-operative analgesia e.g clonidine It may however cause excessive sleepiness in the post-operative period which may delay home discharge. The use of clonidine in preterm babies and infants <3 months is still being debated because of the risk of apnoea.[26] Ketamine as an additive to a caudal block has recently be questioned.[27]

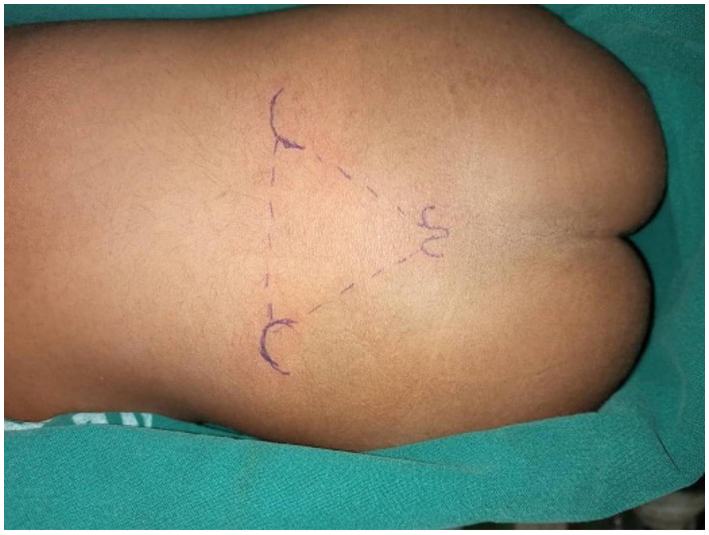

Figure 6: Landmarks for caudal block; posterior superior iliac spines and sacral cornua

General anaesthesia + LA

A general anaesthetic is usually provided for patients outside the neonatal period or for re-do procedures. It requires skilled personnel and equipment to be safely delivered. An inhalational induction with halothane or sevoflurane or intravenous induction with propofol (3-5mg.kg^{-1}) is acceptable. Thiopentone (4-6mg.kg^{-1}) may be used but being a short daycase procedure, delayed recovery should be anticipated. When the choice of anaesthetic agents is limited, intravenous (1-2mg.kg^{-1}) or intramuscular (5-10mg.kg^{-1}) ketamine may be employed. Ketamine delays recovery and produces excessive secretions that may make airway management troublesome. This can be offset by its administration with glycopyrrolate or atropine. Atropine (0.01mg.kg^{-1}) or glycopyrrolate (0.05mg.kg^{-1}) are usually given preinduction if halothane induction is used as it could cause bradycardia.

In facilities with specialist anaesthetists, appropriate perioperative monitoring and resuscitation equipment, it is best to intubate the neonate or small infant and control ventilation. In older infants, the airway can be maintained by insertion of an oro-pharyngeal airway and face mask or the use of an appropriate-sized laryngeal mask airway. Ventilation can then be spontaneous as the procedure is of a short duration <20 minutes. However where these facilities are not available, safety should not be compromised and other methods of providing anaesthesia and analgesia should be used to prevent morbidity and indeed mortality.

Analgesia if not given as premedication is provided by rectal or intravenous acetaminophen as well as diclofenac or ibruprofen after the child has been anaesthetised. However diclofenac is not recommended in children less than 6 months and ibuprofen in children less than 3 months.[16]

One of the regional techniques may also be performed to provide a longer lasting period of post-operative analgesia.

POST-OPERATIVE CARE

In procedures done under non-pharmaological or local anaesthesia techniques, the infant is handed over to the parent for comfort and feeding. The surgical site is checked for oozing and bleeding before discharge home. Standard post-operative care is provided after circumcision under general anaesthesia; monitoring, pain assessment, administration of analgesics and maintenance of normothermia. Some authors recommend that neonates younger than 44 weeks of postconceptional age (PCA) and ex-preterm infants up to 60 weeks PCA should be monitored for at least 24 hours after surgery/general anaesthesia.[17] A widely accepted guideline is to monitor all infants younger than 50 weeks of postconceptional age for at least 12 hours after surgery/general anaesthesia. The incidence of significant apnea/bradycardia is highest in the first 4 to 6 hours after surgery, but has been reported up to 12 hours after surgery.[28] The General anesthesia compared to spinal anesthesia (GAS) trial found that late apnnoea, up to 12 hours can occur after both general and spinal anaesthesia in infants < 60 weeks PCA.[29]

Post-Operative Analgesia after Circumcision

Acetaminophen for neonates <32 weeks is given orally at a maintenance dose of 15mg.kg^{-1} up to 12 hourly with a maximum daily dose of 45mg.kg^{-1}. Neonates >32 weeks can receive a maintenance dose of 15mg.kg-1 up to 6 hourly with a maximum daily dose of 60mg.kg^{-1}.

For children 1-2 months, a maintenance oral dose of 15mg.kg^{-1} up to 4 hourly, with a maximum daily dose of 90mg.kg^{-1} is recommended. The maximum daily dose should not exceed 48 hours in neonates and 72 hours in infants.[16] Acetaminophen produces satisfactory post-operative analgesia. Ibuprofen can also be added orally at a dose of 5-10mg.kg^{-1} up to 6 hourly in infants >3 months. In infants >6 months, diclofenac administered by oral or rectal route at 1-3mg.kg^{-1} up to 3mg.kg^{-1} in divided doses.[16]

Lidocaine gel may also be applied immediately after the procedure for effective post-operative analgesia.

Complications of neonatal or infant male circumcision

Elective newborn or infant circumcision remains a common and controversial practice. When carried out by trained skilled personnel, complications are rare.

Anaesthetic Complications

In skilled hands, these are uncommon but may include difficulty with venous cannulation, laryngeal spasm and bradycardia with airway instrumentation, difficult intubation, hypothermia and delayed recovery.

Surgical Complications[30,31]

Early adverse events or complications are usually minor and readily treatable. They include bleeding, minor infection, pain, incomplete separation or retention of device used for circumcision and parental dissatisfaction with appearance. Severe early complications occur rarely and include penile injury, ablation of the phallus and uretherocutaneous fistula. In very rare cases death may occur from excessive bleeding. Late complications include excessive residual skin or incomplete circumcision, adhesions, meatal stenosis, phimosis etc

Post-circumcision Bleeding

Post circumcision bleeding may be a result of excessive skin removal, insufficient clamp positioning or improperclamp size. It may also be due to injury to the frenular artery during separation of adhesions at the 6 o'clock position.

Other causes may be an underlying coagulopathy such as haemophilia or Von Willebrands factor deficiency or breast-feeding mothers on anticoagulants.

Bleeding is controlled by:

- Simple application of pressure
- Haemostatic agents e.glsurgicel for venous oozing
- Pulsatile bleeding, suggestive of an arterial source will require a stitch or cautery

CONCLUSION

Neonatal and infant male circumcision is widely practiced across the world. Circumcision without adequate pain relief has far-reaching effect on the child even in later years. The notion that neonates do not feel pain should be dispelled and these children offered some pain relief and comfort through non-pharmacological or pharmacological interventions. Regional anaesthetic techniques have the added advantage of extension of analgesia into the post-operative period.

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Update in
Anaesthesia

Anaesthesia for omphalocele and gastroschisis repair

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Abstract

Omphalocele and Gastroschisis are congenital abdominal wall defects which present with herniation of abdominal contents requiring correction. They may be associated with other congenital anomalies. Large defects present with hypothermia, dehydration and risk of infection. They should be promptly corrected for improved outcome. Management may be by primary closure, staged closure, use of silo or desiccating agents. Abdominal compartment syndrome may occur with primary closure of a large defect. Some neonates will require ventilation and total parenteral nutrition in the post-operative period.

INTRODUCTION

Congenital anomalies are important causes of neonatal and infant deaths especially among resource – poor families and countries because of lack of early detection, unavailability of sophisticated equipment for safe repair and inadequate post – operative management. Congenital anomalies accounted for 87% of neonatal surgical cases in Ghana and 96% of deaths.[1]

Congenital anomalies are structural or functional anomalies that occur during intrauterine life such as congenital abdominal wall defects. They can be identified prenatally, at birth or sometimes detected later in infancy.Thus surgical repair is common in the newborn period. Patients born with one anomaly, particularly of midline structures, often have others especially congenital heart diseases.[2]

Abdominal wall defects are congenital malformations with an opening in the abdomen through which various abdominal organs can protrude. Omphalocele and gastroschisis are the most commonly encountered. Other less common abnormalities include[2]:

- *Ectopia cordis* – complete or partial protrusion of the heart through a defect in the thoracoabdominal wall
- B*ladder exstrophy* – defect in lower abdominal wall and pelvis with associated genitourinary abnormalities
- *Cloacal exstrophy* – bladder exstrophy with an imperforate anus

Gastroschisis is a defect in the anterior abdominal wall usually on the right side of the umbilicus, causing herniation of the abdominal contents without a covering sack. It is a surgical emergency.

Omphalocele (exomphalos) is a central umbilical defect with herniation of abdominal contents which may include other abdominal organs e.g. liver and spleen into the umbilical sac. It results from failure of the gut to return to the abdominal cavity during foetal development, resulting in persistent herniation through the extra embryonal part of the umbiblical cord which covers it. The umbilical sac may be intact or ruptured. A ruptured sac constitutes an emergency.

Worldwide the incidence of omphalocele is reported to be 1-3 in 10,000 -13,000 births while that of gastroschisis is 1 in 4,000 – 10,000 live births.[3,4,5] The mortality rates of gastroschisis vary widely across the world with < 5% in high income countries and 75 – 100% in low – income countries.[6] Reports from West Africa show a high mortality of 60- 88% with ruptured omphalocele and gastroschisis.[3,7] This may be because of the need for emergency surgery in compromised neonates, the presence of sepsis and the lack of adequate neonatal critical care facilities in the region.[1]

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Table 1: Major Differences between Omphalocele and Gastroschisis

	Omphalocele	**Gastroschisis**
Anatomical defect	Failure of abdominal wall development during the 3rd embryonic month	Congenital weakness in the body wall due to defective growth or impaired midline fusion
Consequence of defect	Midgut prevented from returning to abdomen but remain within extra-embryonic coelem (amniotic cavity)	Intestines herniated into amniotic cavity
Aetiology	Genetic aetiology	Multifactorial – Environmental and susceptible hosts
Associations	Older, overweight/ obese mothers Trisomy 13, 18 and 21 Beckwith-Wiedemann syndrome Pentalogy of Cantrell	Young mothers with low or normal pre-pregnancy weights Low gravidity Prematurity, small for age babies
Covering sac	Present	Absent
Prenatal diagnosis	Elevated maternal serum alpha-feto protein In-utero ultrasonography	Elevated maternal serum alpha-feto protein (more than omphalocoele) In utero ultrasonography Polyhydramnios
Size of defect	Vary from 4 – 12 cm > 8cm is termed Omphalocoele major	Usually ≤ 5cm
State of GUT	Normal	Oedematous with membranous covering and thickened mesentry due to direct contact with amniotic fluid which triggers an inflammatory reaction.

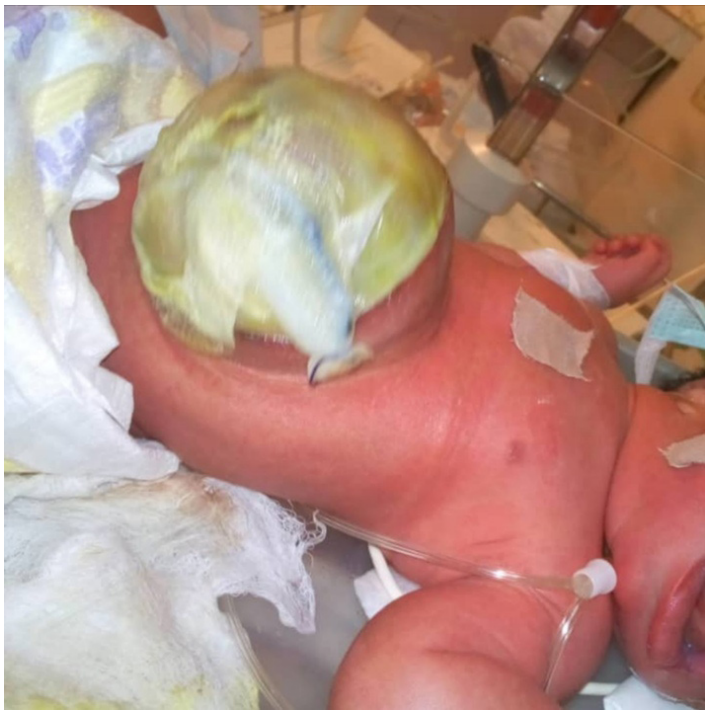

Figure 1: Large Omphalocele at presentation with protective sac covering the bowel. *Picture courtesy of Professor Emmanuel A. Ameh, Professor of Paediatric Surgery, National Hospital Abuja.*

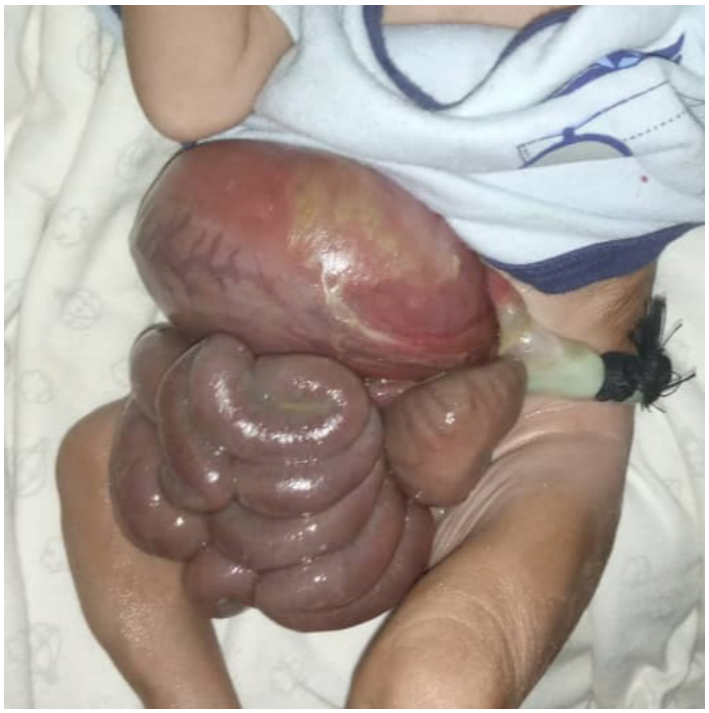

Figure 2: Gastroschisis at presentation with no protective sac but thickened bowel as a result of exposure to amniotic fluid. *Picture courtesy of Professor Emmanuel A. Ameh, Professor of Paediatric Surgery, National Hospital Abuja.*

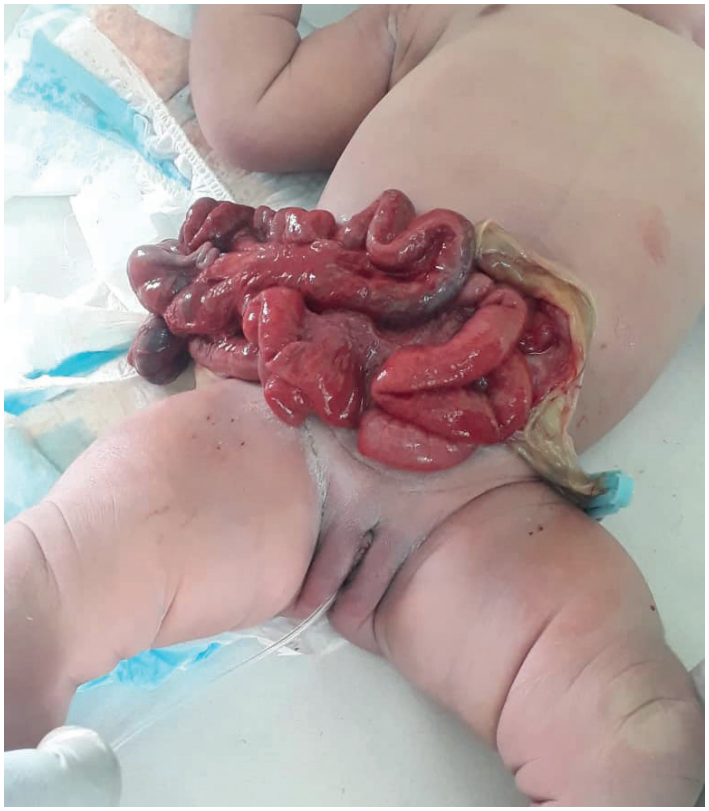

Figure 3: Ruptured Omphalocoele showing normal gut and edge of umbilical sac. *Picture courtesy of Prof Moufa Tambo, l'HôpitalGynéco-Obstétrique et Pédiatrique de Yaoundé.*

PRENATAL DIAGNOSIS

When prenatal diagnosis has been made usually by ultrasound, delivery should ideally be scheduled in a center capable of providing adequate neonatal care and surgical repair of the defect. Delivery by elective caesarean section helps to minimise or eliminate further damage to the intestines and external abdominal organs. Management of these neonates is multidisciplinary involving neonatologists, surgeons, anaesthetists and obstetricians.

SURGICAL MANAGEMENT

Surgical closure of the defect vary in timing and urgency and is determined by the following:

- *The type of defect* – the urgent repair of gastroschisis is advocated to minimise continued heat and evaporative losses as well as the risk of infection or gut perforation
- *Whether the sac is ruptured* – A ruptured sac requires urgent repair
- *Size of defect* – a large defect > 8cm will necessitate a staged procedure as it would be difficult to fit all the herniated gut into the abdomen without compromising blood supply and ventilation. Conservative management is preferable where neonatal Intensive care Unit (ICU) facilities are not available or the defect is large.
- Presence of other intestinal malformations e.g.malrotation, intestinal atresia

a) *Primary Closure* - Small defects can be closed without difficulty. Primary closure in large defects can result in increased intra-abdominal pressure with compromised organ blood flow and ventilation.

b) *Silo* - A staged approach is used for the closure of large ruptured omphalocele or gastroschisis. The bowel is put in a "silo" or 'tent' with its rim sutured to the edges of the abdominal defect. This silo is gradually reduced in size over a period of approximately 7 days in the neonatal intensive care unit. This provides time for the abdomen to accommodate the herniated contents. Thereafter, the silo is removed and the defect closed surgically at a later time.Various types of silo exist (commercial and locally fabricated) with the same basic mode of operation.

The Silo is preferable in regions where neonatal intensive care, neonatal anaesthetists and paediatric surgeons are limited and has been shown to improve mortality in intact omphalocoele.[8]

c) *Topical Agents "Paint and Wait" technique* - A desiccating agent is applied topically to the intact defect under a gauze wrap. This encourages escharification and epithelisation of the defect leaving a ventral hernia,which can then be closed at a later stage frequently with the use of a synthetic or biological mesh. Agents commonly employed are 1% silver sulphadiazine ointment, povodine – iodine with or without a powdered antibiotic combination (polymyxin, bacitracin and neomycin) or honey. Other agents are silver nitrate solution, sofratulle and gentian violet. Complications of topical agents include leucopenia with silver sulphadiazine, hypothyroidism with povodine – iodine and argyrism with silver nitrate.[9]

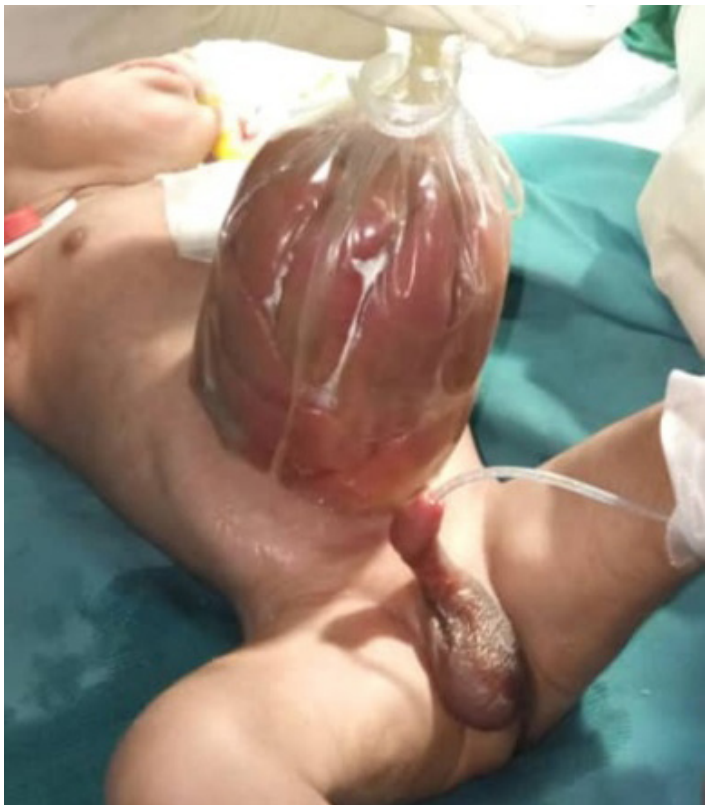

Figure 4: Same gastroschisis baby after application of preformed silo Picture courtesy of Professor Emmanuel A. Ameh, Professor of Paediatric Surgery, National Hospital Abuja.

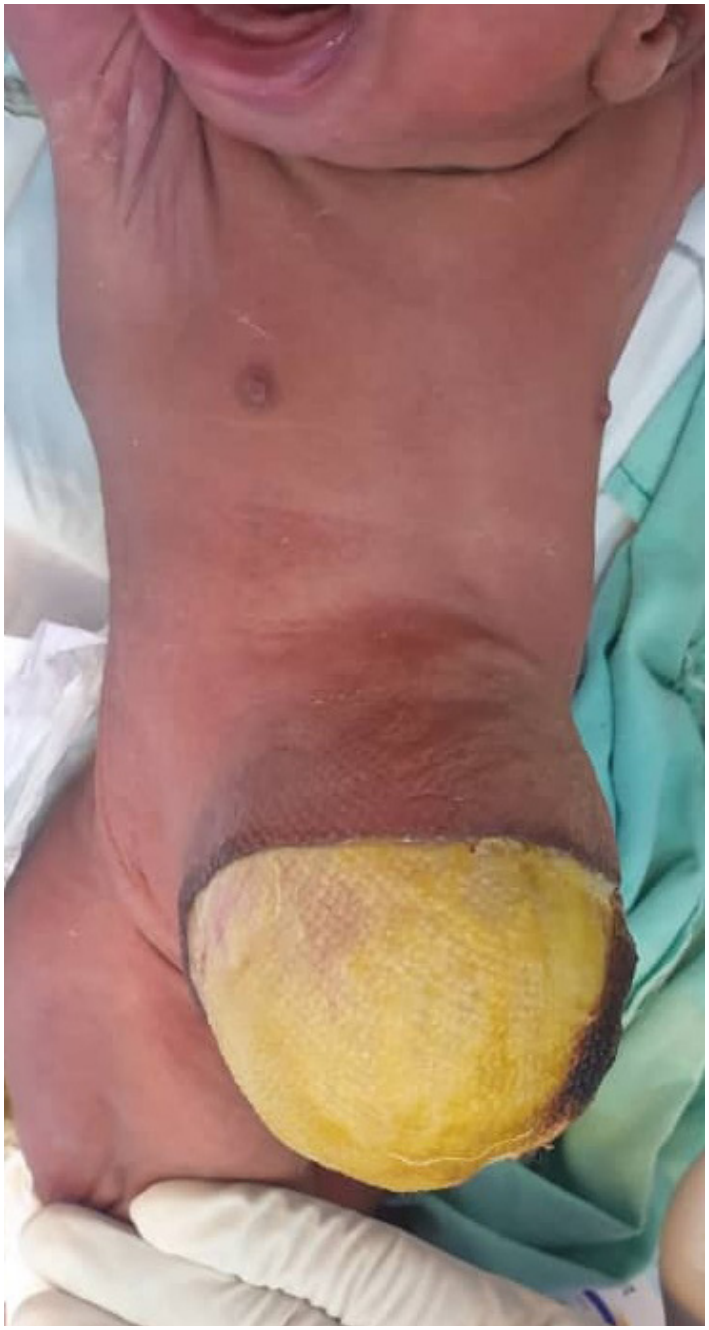

Figure 5: Same omphalocele baby after 2 weeks of dressing with 1% silver sulphadiazine. Picture courtesy of Professor Emmanuel A. Ameh, Professor of Paediatric Surgery, National Hospital Abuja.

PREOPERATIVE ASSESSMENT AND MANAGEMENT

A neonate born with omphalocele or gastroschisis should be immediately wrapped, transported to a specialised unit and nursed in an incubator for further care. This limits the heat and moisture loss. If no incubator is available, a radiant heater may be used after ensuring the defect is well covered with a clean cellophane cover or moistened gauze. The neonate should be nursed in the lateral position with the bowel supported in order to prevent compression of blood vessels and bowel loss. Resuscitation should focus on restoring and maintaining normothermia and adequate hydration.

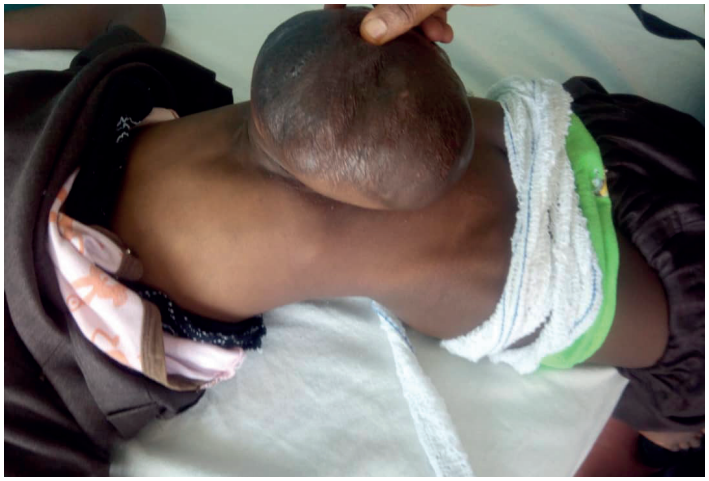

Figure 6: Ventral hernia post conservative management of omphalocelemajor. Picture courtesy of Paediatric Surgical Unit, Lagos University Teaching Hospital.

With a large defect, it is sometimes necessary to intubate and ventilate the neonate pre – operatively. A nasogastric (NG) tube is passed to decompress the stomach and prevent aspiration of stomach contents.

Fluid resuscitation is commenced with maintenance fluids of 10% Dextrose/Water at 80ml.kg.day^{-1}. Boluses of 20ml.kg^{-1}of normal saline or 10ml.kg^{-1} of 4.5% albumin may be required to maintain normovolaemia when huge evaporative losses have occurred.[5] Potassium replacement is commenced once urine output has been established. The deficit is calculated and added to the daily maintenance dose of 2.5mmol.kg^{-1} and administered at a rate of 0.3-1mmol.kg.$^{-1}$hr.-1[10] Capillary refill, pulse rate and urine output are used to monitor the adequacy of resuscitation.

Antibiotic therapy is commenced to prevent infection using broad spectrum antibiotics like cephalosporins and metronidazole.

When the child is optimised and scheduled for surgery, pre-anaesthesia assessment and preparation should include:

- Detailed history of pregnancy and birth, gestational age, birth weight and APGAR score at birth as well as any relevant drug history are obtained (routine vitamin K, antibiotic therapy).
- *Cardiac assessment* is performed to determine the presence of any associated cardiac defects as septal defects are common. This should ideally include an echocardiogram. A cardiologist's review may be helpful.
- *Respiratory assessment* - A chest x-ray (CXR) may be indicated if aspiration or infection is suspected. A large omphalocele may present with an underdeveloped thoracic cavity, restrictive lung disease and pulmonary hypoplasia. Further respiratory compromise occurs with reduction of the herniated contents into the abdomen. Many of these neonates will require post-operative respiratory support.
- *Airway assessment* - Neonates are notoriously difficult to intubate especially in unskilled hands. In addition, some of these babies present with micrognathia or macroglossia as in Beckwith Wiedeman syndrome which may compound the intubation difficulty

Table 2: Anaesthetic Considerations of Omphalocele and Gastroschisis

	Gastroschisis
Age	Neonate may be preterm or small for age Associated anomalies -chromosomal, cardiac, respiratory, airway Risk of intraventricular haemorrhage and reversal of shunt
Defect	Large evaporative losses Large heat loss Risk of infection Risk of gut perforation
GIT	Full stomach Nutritional support
Surgery	Staged procedure Abdominal compartment syndrome Hypothermia
Post-operative	Elective ventilation Nutritional support

- *Circulatory assessment* is done to determine the hydration and volaemic status of the neonate using skin perfusion, capillary refill, heart rate (HR), blood pressure (BP), core-peripheral temperature gradient and urine output.

Investigations

Routine full blood count, electrolytes, urea and creatinine should be performed. A raised white cell count is suggestive of infection. The haemoglobin level should be at least $10g.dl^{-1}$ for surgery. If a chest x-ray and echocardiogram have been performed as indicated above, they should be reviewed. Arterial blood gases analysis using lactate levels and base excess will demonstrate if fluid resuscitation has been adequate.

Blood should be cross matched and made available for surgery.

INTRA-OPERATIVE MANAGEMENT

Prior to the arrival of the child in theatre, active measures should be taken to minimise heat loss which is aggravated by the exposed abdominal contents. The ambient theatre temperature should be maintained at 25 - 26°C. Additional means of maintaining normothermia should be employed e.g fluid warmer, warming mattress etc. In situations where these are unavailable; it is imperative that the child is kept covered at all times. A simple cellophane bag can be used to wrap round the neonate. Temperature monitoring is vital to assess the effectiveness of measures being instituted and ensure that the baby does not become hyperthermic.

Routine anaesthesia checklist must be performed prior to the arrival of the child which includes the anaesthesia machine, source of oxygen, suction machine and a trained assistant.

Airway equipment should include– laryngoscope with size 1 Miller or Macintosh blades, endotracheal tubes (ETT) sizes 2.5, 3.0 and 3.5 mm ID, sizes 00 – 1 oro-pharyngeal airways and a Mapleson F breathing system.

Resuscitation drugs should be drawn and labelled; suxamethonium $2mg.kg^{-1}$and atropine $20mcg.kg^{-1}$ x 2 doses as well as the patient's dose of all anaesthetic drugs.

Standard monitoring should include precordial stethoscope, electrocardiogram (ECG), blood pressure (BP), peripheral oxygen saturation (SPO_2), end-tidal carbon dioxide ($ETCO_2$) and core temperature monitoring. It is important that the appropriate-sized attachments (cuff, electrode, probes) are used to ensure accurate readings. Intra-arterial blood pressure and central venous pressure (CVP) monitoring may be beneficial in very sick neonates. A manometer line is placed in the bladder via a Foley catheter or in the stomach via a nasogastric tube to monitor intra-abdominal pressure in neonates scheduled for primary closure of defect. Blood glucose monitoring is recommended.

A rapid sequence induction is preferable as these neonates are classified as a 'full stomach'. The nasogastric tube is aspirated prior to induction. For many neonates, pre-induction atropine $10mcg.kg^{-1}$ is employed because of their propensity to develop bradycardia with administration of suxamethonium or halothane and during laryngoscopy. Bradycardia will further compromise the cardiac output. After pre-oxygenation, induction can be achieved using thiopentone $2mg.kg^{-1}$ if resuscitation has been adequate, or ketamine $1\text{-}2mg.kg^{-1}$ if fluid deficits still exist. Even with adequate fluid resuscitation, some of these neonates may become severely hypotensive after the use of thiopentone. Cricoid pressure is then applied and suxamethonium $2mg.kg^{-1}$administered to facilitate intubation. As many neonates do not fasciculate after suxamethonium, a timing principle is used. Alternatively, if the neonate is fit and the defect is small, an inhalational induction with sevoflurane or halothane in oxygen is employed and intubation is facilitated with atracurium. Despite adequate pre-oxygenation, desaturation during laryngoscopy and intubation can still occur

due to decreased functional residual capacity (FRC) and increased oxygen consumption in neonates. This may be aggravated if there is on-going sepsis.

After tracheal intubation and confirmation of its correct position by auscultation and capnography, the tracheal tube is firmly secured as slight movements may result in endobronchial intubation or accidental extubation. An air leak should be audible with manual ventilation to prevent post-operative airway oedema due to undue compression on the tracheal mucosa.

Muscle relaxation is provided with any intermediate non-depolarising muscle relaxants and positive pressure ventilation instituted using a neonatal ventilator or manual ventilation with a Mapelson F breathing system. Airway pressure is closely monitored especially during closure of the defect. Maintenance of anaesthesia is with sevoflurane or isoflurane in oxygen and air. Halothane delays recovery, is metabolised by the liver and causes bradycardia, therefore should ideally be avoided. Its use is contraindicated in the presence of jaundice. The use of nitrous oxide is contraindicated as it diffuses into air-filled spaces resulting in more distension of the bowels.

Analgesia can be provided by a single-shot caudal epidural, caudal with catheter or epidural with catheter using bupivacaine. A central neuraxia block also provides abdominal muscle relaxation which is essential for successful surgery. Alternatively, a multi-modal approach using fentanyl and paracetamol is adequate. If post-operative elective ventilation is planned, a long-acting opioid like morphine is preferable. Infiltration of the surgical site with bupivacaine at the end of surgery is useful where a caudal block has not been established.

Fluid management is aggressive as the 3rd space loss is significant due to large evaporative losses with major defects. Ringers lactate is adequate for maintenance but 10% glucose should be added for premature, small for age and sick neonates. Saline or colloid at 10 – 20mls.kg^{-1} is employed to replace the 3rd space losses. This is governed by clinical cardiovascular parameters especially increasing heart rate, delayed capillary refill and cold extremities. All fluids should be warmed and administered through a paediatric infusion set e.g. burretrol. Inotropes e.g.dopamine infusion are sometimes necessary to maintain normotension.

Blood loss is closely monitored and transfusion given when required. Blood is transfused after a loss of > 10% of the baby's blood volume; 90mls.kg^{-1} in term neonates and 100mls.kg^{-1} in preterm neonates. In procedures involving large defects, blood loss may be significant and fresh frozen plasma (FFP) and cryoprecipitate may be required

Alternative anaesthetic techniques have been employed to eliminate the need for general anaesthesia and the associated risks even in skilled hands as well as the need for post-operative ventilatory support in resource limited countries. Central neuraxial blocks have been successfully used in surgical repair of omphalocele and gastroschisis. These blocks will provide abdominal relaxation without the need for muscle relaxants and opioids. The neonate is usually kept breathing spontaneously and fully monitored throughout the procedure with oxygen administered through a Mapleson F breathing system. The feasibility of replacing the bowel contents into the abdominal cavity can be monitored by the development of respiratory difficulty in the spontaneously breathing child. A pulse oximeter placed on a lower limb helps monitor replacement of abdominal contents without compromising circulation. The following regimens have been used by different authors:

- *Caudal anaesthesia* - 0.5% bupivacaine and 2% lidocaine with adrenaline 1:200,000 in a total volume of 1.25ml.kg^{1} after sevoflurane induction to produce immobility during the siting of the caudal block.[11]
- Combined spinal and caudal epidural using 0.5mg of 0.5% bupivacaine + 0.5mcg of fentanyl to a total volume of 0.2ml injected into the subarachnoid space. Thereafter, a 21G catheter was threaded through the caudal space to an approximate level of T8. Epidural top-ups of 0.2% bupivacaine 0.5 ml were given intra and post-operatively.[12]

Surgical considerations

An attempt to reduce a large omphalocele results in increased intra-abdominal pressure and abdominal compartment syndrome. Intra-abdominal pressure >20mmHg is likely to result in abdominal compartment syndrome. There is splinting of the diaphragm and respiratory insufficiency evidenced by rising peak inspiratory pressure >30cmH_2O.[13]

Tidal volume falls and the hypoventilation that occurs results in hypercarbia and hypoxia. If inspiratory pressure cannot be measured, the 'tightness' of the reservoir bag during manual ventilation along with other clinical signs may indicate reduced pulmonary compliance. Venous return is compromised with a fall in blood pressure and urine output. Intra-gastric or intravesical pressures may exceed 20cmH_2O. If uncorrected, reduced mesenteric blood flow results in bowel ischaemia and subsequent necrotising enterocolitis. Renal failure, sepsis and wound breakdown can also occur. A second pulse oximeter probe placed on the foot will detect loss of the foot pulse oximeter waveform as an indication of an overly tight abdominal wall closure.

Surgical exposure of the bowel results in large evaporative losses which can be difficult to correct. The bowels should therefore be covered with a warm moist gauze or kept in a bag during surgery. Heat loss is minimised by employing warm irrigation fluids.

POSTOPERATIVE MANAGEMENT

At the end of surgery, well resuscitated neonates with a small defect can be extubated after reversal of muscle relaxants using neostigmine and atropine or glycopyrrolate. The NG tube is suctioned and the neonate extubated awake; breathing spontaneously, normotensive, normothermic, normoglycaemic and with purposeful movements. They should be nursed in a specialised ward with cardiovascular, respiratory and temperature monitoring, oxygen therapy and fluid therapy.

Most of the patients following repair of major omphalocele or gastroschisis should be admitted into ICU unextubated for ventilatory support. Some may require muscle relaxation. Analgesia is provided with intravenous morphine for those on mechanical ventilator, epidural local anaesthetics by infusion or boluses and intravenous paracetamol.

Total parenteral nutrition (TPN) is continued till return of bowel function which may take several weeks especially in gastroschisis. Where TPN is not available, infusions of amino acids and lipids have been utilised with varied responses.[3] Fluid, electrolyte, glucose and temperature maintenance must be addressed during this time.

CONCLUSION

Abdominal wall defects in neonates may be small or large, with an intact or ruptured sac. The size and type of the defect determines the severity of heat and evaporative losses and the risk of infection. Operative management may be primary or staged closure. Intra-abdominal compartment syndrome and hypothermia are major intra-operative concerns to the anaesthetist. Some neonates will need post – operative ventilation. Prenatal screening and protocol for management should be adopted in resource – poor countries to ensure a good outcome. Optimal management will require a multidisciplinary approach with an anaesthetist, intensivist, surgeon, neonatologist and obstetrician.

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Clinical Review

Update in
Anaesthesia

Hypertrophic pyloric stenosis in infants

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Abstract

Hypertrophic pyloric stenosis is a common condition, occurring in 1 out of 500 live births. Boys are affected more than girls, with a ratio of 4:1. Presentation is usually between 2 – 6 weeks of life with classical non-bilious projectile vomiting. Examination will reveal a dehydrated child with a palpable olive-shaped mass located between the midline and right upper quadrant. The lesion is commonly delineated by ultrasonograpgy. The exact cause is largely unknown, however several theories have been advanced, which include genetic and environmental factors.

It is not a surgical emergency, so the initial management is aimed at resuscitation that will correct dehydration, electrolyte and acid-base disturbances before proceeding to surgery. Rapid sequence intravenous induction, endotracheal intubation and muscle relaxation is the anaesthesia technique of choice. Post operative apnea is a possibility, and such monitoring should continue well into the postoperative period.

Key words: hypertrophic; pylorus; stenosis; infants; anaesthesia

INTRODUCTION

Hypertrophic pyloric stenosis in infants is the narrowing of the gastric outlet caused by hypertrophy of the muscularis layer of the pylorus. The aetiology is unknown but there is a genetic predisposition. The incidence is approximately 1 in 500 live births, boys are affected more than girls, with a ratio of 4:1. A total of 40–60 percent of cases occur in the first-born children. It is the commonest cause of intestinal obstruction in infancy requiring surgery.

Gastric carcinoma and chronic peptic ulceration can also give rise to acquired pyloric stenosis in adults. However, this article will focus on congenital pyloric stenosis that occurs in neonates or early infancy.

Aetiology

The exact cause is largely unknown, however several theories have been advanced, which include genetic and environmental factors.

Risk Factors

Risk factors for pyloric stenosis include:

- ***Sex***. Pyloric stenosis is seen more often in boys — especially firstborn children — than in girls.
- ***Race***. Pyloric stenosis is more common in whites of northern European ancestry, less common in African-Americans and rare in Asians.
- ***Premature birth***. Pyloric stenosis is more common in babies born prematurely than in full-term babies.
- ***Family history.*** Studies found higher rates of this disorder among certain families. Pyloric stenosis develops in about 20 percent of male descendants and 10 percent of female descendants of mothers who had the condition.
- ***Smoking during pregnancy***. This behavior can nearly double the risk of pyloric stenosis.
- ***Early antibiotic use***. Babies given certain antibiotics in the first weeks of life - erythromycin to treat whooping cough, for example - have an increased risk of pyloric stenosis. In addition, babies born to mothers who took certain antibiotics in late pregnancy may have an increased risk of pyloric stenosis.
- ***Bottle-feeding***. Some studies suggest that bottle feeding rather than breast-feeding can increase the risk of pyloric stenosis. Most of the people who participated in these studies used formula rather than breast milk, so it isn't clear whether the increased risk is related to formula or the mechanism of bottle-feeding.

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Clinical Presentation

Pyloric stenosis usually manifests within weeks 2 to 6 of life with non-bilious vomiting that is projectile. The infant normally feeds well but vomits after each feed. There may be weight loss.

Examination will often reveal a dehydrated child with a palpable olive-shaped mass, typically 1-2cm in diameter located between the midline and right upper quadrant. The lesion is commonly delineated by ultrasonography or rarely with barium swallow and radiographic examination. Sometimes, this typical olive-shaped mass may not be palpated on examination or easily delineated by ultrasonography, diagnosis in this instance, will be based on high index of suspicion.

Arterial blood gas will show a marked metabolic alkalosis with hypokalaemia and hypochloraemia, especially when the patient presents late. In resource intense areas, this finding is no longer as common, as early suspicion allows diagnosis prior to extensive derangement of electrolytes. Urinalysis will reveal acidic urine with high level of potassium. Hypoglycaemia, mild uraemia, unconjugated hyperbilirubinaemia and haemoconcentration may also be seen.

Pathophysiology of the ABG picture

The blood gas results of hypokalemic hypochloraemic metabolic alkalosis seen in this condition are due to a combination of gastrointestinal, renal and respiratory changes.

Gastrointestinal: The vomitus in pyloric stenosis is mainly gastric fluid rich in hydrochloric acid. It is devoid of bicarbonate mixing due to the pyloric obstruction preventing bicarbonate from the small intestine to mix with the gastric fluid, as seen in normal vomitus. As a result of this only hydrogen and chloride ions are lost.

Renal: Due to these biochemical changes, the kidney is presented with a large bicarbonate load. This exceeds the absorptive threshold of the kidneys leading to alkaline urine that is seen initially. However, prolonged vomiting leads to hypovolaemia and dehydration. This in turn causes the activation of renin-angiotensin-aldosterone axis in an attempt to restore circulating volume. The aldosterone acts on the kidney to retain sodium at the expense of potassium and hydrogen ions. This leads to production of paradoxical aciduria and worsening of hypokalaemia and metabolic alkalosis.

Respiratory: The infant may try to compensate for the metabolic alkalosis by using the respiratory system. They may hypoventilate to produce hypercapnia, but this is never sufficient to correct the alkalosis, as the hypoxic drive will be triggered.

Other biochemical and haematological findings will include; hypoglycaemia, haemoconcentration, mild uraemia and unconjugated hyperbilirubinaemia .

Preanaesthetic consideration

The preoperative considerations can be divided into considerations that are specific to the pyloric stenosis and general consideration of paediatric anaesthesia.

Issues relating specifically to pyloric stenosis include: markedly deranged acid-base status, the effect of dehydration and the increased risk of regurgitation owing to the obstruction. Pyloric stenosis is not a surgical emergency, as such the infant should be fully resuscitated, and electrolyte abnormalities fully corrected before surgical intervention.

The challenges of anaesthetising a small infant include the altered anatomy and physiology, the presence of anxious parents, difficulty obtaining intravenous access and altered drug dosages.

Resuscitation

Resuscitation should take place under the watchful eyes of nursing staff that are well trained to take care of such cases, preferably in special care baby unit. Start by assessing the degree of dehydration (Table 1) and securing intravenous access. At same time take blood sample for full blood count, liver function test, electrolyte, urea and creatinine, as well as blood gases. These will serve as baseline to guide resuscitation and help determine the required potassium supplementation. Insert a nasogastric tube to remove gastric residue and perform a four hourly gastric washout to reduce the risk of aspiration. Regular monitoring which should include: urine output, blood pressure, heart rate, respiratory rate and oxygen saturation, as well as repeat blood gases will help ascertain the success of resuscitation.

Fluid management

Fluid management can be divided into resuscitation fluid, maintenance fluid and ongoing losses.

Resuscitation fluid: 0.9% Normal saline or Hartmann's solution should be used as resuscitation fluid, and it is calculated by assessing the degree of dehydration. The volume of fluid required can be calculated by multiplying the percentage dehydration by the weight of the infant multiplied by ten (% dehydration x body weight(kg) x 10). Half of the fluid deficit should be given within the first 24 hours and the other half given over the second 24 hours.

Table 1: Assessment of degree of dehydration

History	Examination	Degree	Clinical presentation
Frequency of vomiting, how much the infant takes orally, frequency of wet diapers, any associated diarrhoea and fever	Look for dry mucous membrane, a sunken fontanelle and eyes, tachycardia, hypotension, prolonged capillary refill and decreased level of consciousness	5%	Dry skin and mucous membrane
		10%	Cool peripheries, depressed fontanelle and oliguria
		15%	Hypotension and changes in level of consciousness

Alternatively, the resuscitation fluid can be given based on the initial values of serum electrolytes, especially serum chloride (Cl-) as follows:

- Cl- value < 85mmol/l give three boluses of 20ml/kg separated one hour apart
- Cl- value ≤ 97mmol/l give two boluses of 20ml/kg separated one hour apart

Maintenance Fluid: in addition to the resuscitation fluid, maintenance fluids are given in the form of Hartmann's solution or 0.45% saline with 5% dextrose, using the 4-2-1 rule (as described in table 2) to determine the hourly maintenance fluid.

Ongoing losses: Nasogastric drain or aspirate should be estimated and replaced using Hartman's solution.

Potassium replacement

Provided renal function test is within normal limit, 3mmol/kg/24 hour of potassium should be added to the maintenance fluids, as guided by regular blood gas analysis.

Intraoperative consideration

The anaesthetist should aim at achieving a urinary output of 1–2ml/kg/hr, if patient is catheterized, or the infant has had two wet diapers over 4–8 hours; as well as the following biochemical parameters;

- serum chloride concentration of above 97mmol/l
- bicarbonate of below 30mmol/l
- PH less than 7.5 with a base excess less than 6mmol/l and
- potassium concentration that is within normal limit, before proceeding with the case.

The procedure can be done laparoscopically or open and entails making an incision into muscularis layer of the pylorus making sure not to breech the mucosa. It lasts for between 30 minutes to 1 hour depending on speed and expertise of the surgeon. Prior to induction, the nasogastric tube should be aspirated, attempting to suction the four quadrants of the stomach by turning the infant accordingly. Standard monitors should be attached as per AAGBI guideline.

Rapid sequence induction with or without cricoid pressure is the induction technique of choice, using ketamine, sodium thiopentone or propofol depending on haemodynamic parameters. However, inhalational induction using sevoflurane or halothane, after an ultrasound confirmation of an empty stomach, has also been reported. The main reason that was advanced by the proponents of inhalational induction is avoidance of hypoxia in the infant that already has reduced oxygen reserve due to reduced functional residual capacity.

Tracheal intubation is facilitated with 1–2mg.kg^{-1} of suxamethonium. The airway should be secured using an appropriate sized endotracheal tube, throat packed, tube secured with adhesive tape and the infant connected to the machine via an Ayre's T-piece or circle system using pressure controlled ventilation mode. An intermediate or long-acting non-depolarizing neuromuscular blocker is given when the effect of suxamethonium has worn off. Fentanyl, paracetamol and local anaesthetic skin infiltration can be used for analgesia. The use of opioids is controversial, especially, if there is significant electrolyte disturbances on presentation. Even when these derangements are corrected, there is still a higher incidence of respiratory depression. Anaesthesia should be maintained with volatile agent/N_2O/O_2 combination (avoid nitrous if surgery is to be done laparoscopically).

Isotonic fluid (0.9% saline or Ringers lactate/Hartmann's) at 10ml/kg should be used intraoperatively to maintain circulating volume. However, if the infant is on glucose containing fluid preoperatively, that should continue in the intraoperative period with regular blood glucose monitoring to ensure normoglycaemia.

At the end of surgery, residual muscle paralysis is reversed and the infant extubated awake in a left lateral position.

Postoperative consideration

During the postoperative period, vital signs monitoring must continue, including SpO_2 and apnoea monitoring due to the possibility of postoperative apnoea up to 60 weeks post-gestational age, as well as increased incidence of apnoea in the face of electrolyte derangement, even after it has been corrected. Supplemental oxygen is required and intravenous fluid continued until feeding is established, in a graded manner, usually within 6 hours post operatively, unless the bowel mucosa was breached. Analgesia can be achieved with paracetamol, given intravenously at a dose of 7.5mg.kg^{-1} every 4–6 hours and converted to oral when oral intake is established. Alternatively, suppository paracetamol can also be used at a dose of 30mg.kg^{-1} as a loading dose followed by 20mg.kg^{-1} every 8 hours to a maximum of 60mg in 24 hours. However, the smallest suppository is available in 60mg, 125mg and 250mg formulations, meaning that the infant should be at least 2kg to receive the smallest rectal dose.

Table 2: Fluid replacement

	Type of fluid	**Volume of fluid**
Resuscitation fluid	Hartmann's solution or N/saline	% dehydration x Kg body weight x 10
Maintenance fluid	Hartmann's solution or 5% Dextrose in 0.45% saline	4- 2-1 rule 4ml/kg for 1st 10kg 2ml/kg for 2nd 10kg 1ml/kg for each following 10kg
Ongoing losses	Hartmann's solution	As estimated

The practice of cutting the suppository should be avoided because the active drug may not be evenly distributed throughout the wax.

Conclusion

Hypertrophic pyloric stenosis is a common condition, occurring in 1 out of 500 live births. Presentation is usually between 2 and 6 weeks of life with classical non-bilious projectile vomiting. It is not a surgical emergency, so the initial management is aimed at resuscitation that will correct dehydration, electrolyte and acid-base disturbances before proceeding to surgery. Rapid sequence intravenous induction, endotracheal intubation and muscle relaxation is the anaesthesia technique of choice. Post operatively, the infants generally do well. However, postoperative apnea is a possibility, and as such monitoring should continue well into the postoperative period.

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Update in
Anaesthesia

Anaesthesia for neurosurgical procedures - Ventriculo-Peritoneal (VP) shunt and meningomyelocele repair

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Abstract

The anaesthetist providing anaesthesia for paediatric neurosurgical procedures should be aware of safe techniques to provide the child with the best chance at good postoperative neurologic outcomes.

Ventriculo-peritoneal shunt (VP shunt) insertion and meningomyelocele repair are two common paediatric neurosurgical procedures. Anaesthesia for these surgeries should prevent further brain damage and preserve or improve the workings of the central nervous system.

Key words: ventriculo-peritoneal shunt; meningomyelocele repair; paediatric anaesthesia; hydrocephalus; myelomeningocele repair; neuroanaesthesia; anaesthesia for vp shunt; anaesthesia for meningomyelocele repair; anaesthesia for neurosurgery

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VENTRICULO-PERITONEAL SHUNT

Ventriculo-peritoneal shunt (also known as cerebral shunt) is the passage of a shunt from a ventricle in the brain to the peritoneal cavity. The ventricle may be one of the lateral ventricles, the third ventricle or fourth ventricle. Shunt location is usually based on its indication for insertion. The most common ventricle used is the right lateral ventricle because most persons are right-handed (dominant brain hemisphere on the left), thus the left side of the brain is usually spared by surgeons in case complications arise.

VP shunts are mostly inserted to drain cerebrospinal fluid (CSF) to relieve pressure on the brain in cases of hydrocephalus. Hydrocephalus is excessive accumulation of CSF in the brain caused by a problem in its formation, flow or absorption.

CSF is produced predominantly by ependymal cells in the choroid plexuses of the ventricles of the brain, while absorption takes place in the arachnoid granulations in the subarachnoid space. The normal CSF volume in children is 2 to 4 $ml.kg^{-1}$.

The CSF circulates within the ventricles of the brain with the majority produced within the two lateral ventricles. From here, CSF passes through the interventricular foramina to the third ventricle, then the cerebral aqueduct to the fourth ventricle and then into the subarachnoid space. Any factor that leads to excessive production of CSF, blockage of CSF flow or disruption of absorption can cause hydrocephalus.

In infants, because of open fontanelles, there may be no change in intracranial pressure (ICP) in the presence of hydrocephalus, however in severe cases (and in older children whose fontanelles are fused) the elasticity of the skull is exceeded. Hydrocephalus can then result in elevated ICP with resultant compromise of cerebral perfusion and risk of brain herniation if severe. Normal ICP is 0-6mmHg in neonates and infants, 3-7mmHg in toddlers and pre-schoolers and 5-15mmHg in older children.

The relationship between cerebral perfusion pressure (CPP) and intracranial pressure (ICP) is governed by the following equation:

CPP = MAP - (ICP + JVP)

MAP = Mean Arterial Pressure

JVP = Jugular venous pressure (value is usually zero)

VP Shunts usually have three major parts:

- An inflow catheter which drains CSF from the ventricles. It passes from the brain through a small hole in the skull, and then runs under the skin.
- A valve mechanism which regulates differential pressure or flow through the shunt tubing.

Table 1: Indications for VP Shunt/ Causes of Hydrocephalus

Congenital	Acquired
Aqueduct obstruction/ stenosis	Infection e.g. post meningitis
Meningomyelocele	Tumours leading to CSF blockage
Arnold Chiari malformation	Intraventricular haemorrhage
Dandy-Walker syndrome	Trauma
Benign intracranial cysts	Granulomatous conditions
Vein of Galen aneurysms	Subarachnoid haemorrhage
Congenital central nervous system infections	Cysts e.g. Arachnoid cysts
Craniofacial anomalies e.g. craniosynostosis	Surgery
Inherited (X - linked)	

- An outflow catheter that runs under the skin and directs CSF from the valve to the peritoneal cavity.

The distal end of the shunt is placed where there are epithelial cells to absorb CSF. The peritoneal cavity is commonly favoured for shunts as it is easy to access and has adequate space for absorption of CSF; it is also associated with the least morbidity. A subgaleal (under the scalp) shunt can be used in infants who are too small or premature for other types.

Types of Hydrocephalus

Hydrocephalus may be:

- Communicating (non-obstructive) - when there is no obstruction to the flow of CSF but the problem is a defect in absorption of CSF, or over production. (e.g. Post-meningitis).
- Non-communicating (obstructive) - due to an anatomical blockage in CSF flow. (e.g. Aqueduct stenosis).

Epidemiology

The mean global prevalence of isolated hydrocephalus in the paediatric population (≤ 18 years) is 71.9/100,000. When spina bifida-associated hydrocephalus is included, the prevalence increases to 87.8/100,000. Africa has almost double the prevalence of North America because of untreated or poorly treated neonatal meningitis and ventriculitis.

Clinical features of hydrocephalus

The clinical features depend on the age of the child.

0 - 2 years: enlarged head, bulging fontanelles, bulging scalp veins (especially on crying), irritability, lethargy, fever, vomiting, failure of sutures to close.

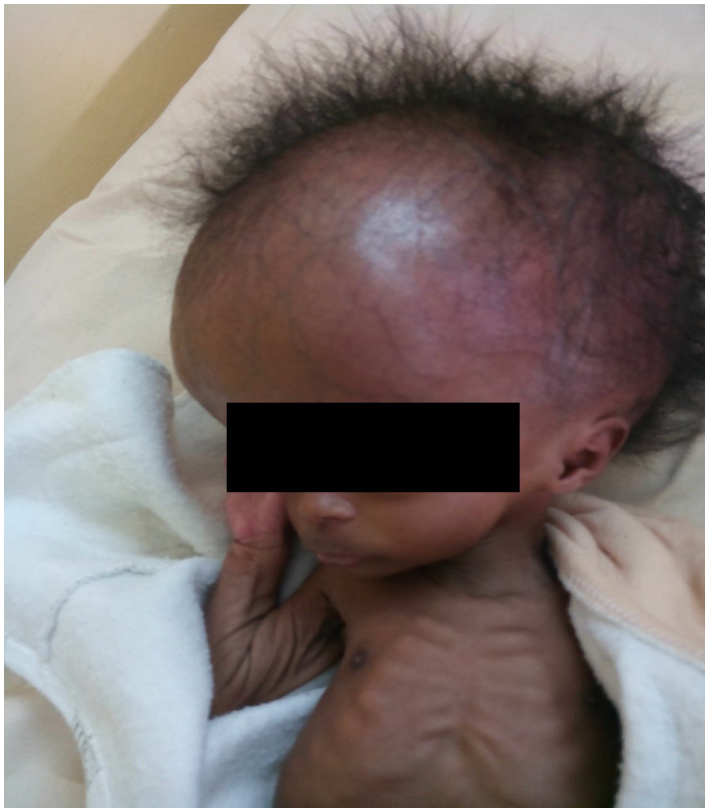

Figure 1: Advanced hydrocephalus with huge head and bulging scalp veins. Picture courtesy of Dr Yusuf AS, Consultant Neurosurgeon, National Hospital Abuja, Nigeria.

'Sun-setting eyes' develop as the case worsens- the eyes are displaced downward and the child is not able to look up; causing the eyes to resemble a sun setting on the horizon.

Impaired vision - caused by compression of the optic chiasma from a dilated 3rd ventricle, occurs in advanced cases.

Nystagmus and random eye movement - result from abducent nerve paresis from stretching of periventricular structures.

Increased deep tendon reflexes and muscle tone in lower extremities (in advanced cases).

Table 2: Types of cerebral shunts

Type of Cerebral Shunt	Location of CSF Drain
Ventriculo-peritoneal (VP) shunt	Peritoneal cavity
Ventriculo-atrial (VA) shunt	Right atrium
Ventriculo-pleural (VPL) shunt	Pleural cavity
Ventriculo-cisternal (VC) shunt	Cisterna magna
Ventriculo-subgaleal(SG) shunt	Subgaleal space
Lumbar-peritoneal (LP) shunt	Peritoneal cavity

Others are: failure to thrive, delayed neurological development, limited control in the head and trunk, high pitched cry, seizures, coma.

Older children: When hydrocephalus occurs in a child after fontanelle closure, the symptoms are somewhat different. They present with normal head size (or mild enlargement), headache, vomiting, irritability, visual impairment, impaired eye movement, lower limb hyperreflexia, urinary incontinence, learning difficulties, seizures, lethargy and altered consciousness.

Untreated or mismanaged hydrocephalus, can lead to personality changes, intellectual disability and gait disturbances.

Investigations for VP shunt insertion

- *Skull X-rays*: enlarged head, craniofacial disproportion, elongated inter-digitations of suture lines (raised ICP in older children).
- *Cranial/ Head/ Brain Ultrasound*: examines the size of the ventricles in very young babies. (Abdominal ultrasound in the pregnant mother can also diagnose hydrocephalus before birth).
- *Computed Tomography (CT) scan*: shows enlarged ventricles and periventricular oedema in hydrocephalus. Enlargement of the 4th ventricle suggests a communicating hydrocephalus. A relatively small 4th ventricle implies obstructive hydrocephalus.
- *Magnetic Resonance Imaging (MRI) of the brain*: shows size of the ventricle. Useful in detecting the cause of the hydrocephalus. E.g. aqueductal stenosis, tumour, Chiari malformations.
- *Transcranial Doppler*: Non-invasive measurement of the middle cerebral artery flow velocities and pulsatility index. This is used to analyse the cerebral circulation; increase in resistance of the cerebral arteries due to increased intracranial pressure is reflected in changes in blood flow velocity.
- *Lumbar puncture/ CSF tap*: for cell counts, protein concentration, and to exclude residual infection (e.g. post meningitic hydrocephalus). A protein concentration > $4g.L^{-1}$ will clog up most VP shunt valves.

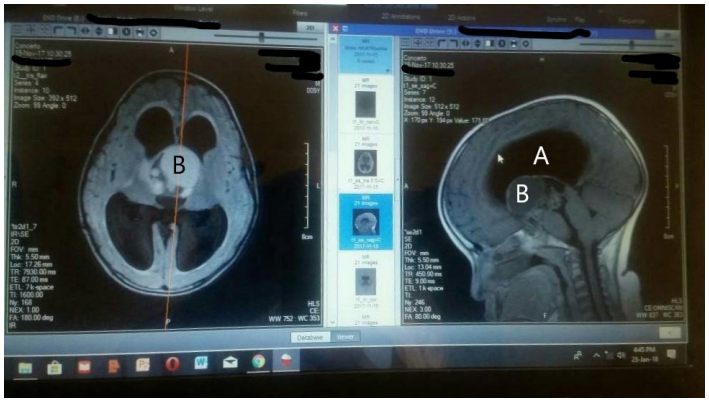

Figure 1: MRI of a 5 year old male showing a huge mass (B) in the region of the Foramina of Monro causing severe obstructive hydrocephalus (A). Picture courtesy of Dr Yusuf AS, Consultant Neurosurgeon, National Hospital Abuja, Nigeria.

Other investigations are

- *Full blood count (Complete blood count)*: leucocytosis if there is infection. Anaemia may be present if the child has feeding problems.
- *Electrolytes, urea and creatinine*: There may be dyselectrolytemia due to vomiting caused by raised ICP.

Treatment of hydrocephalus is mostly surgical. Medical treatment is reserved for selected cases and is usually temporary. The three surgical options are:

- VP shunt
- Endoscopic Third Ventriculostomy (ETV) - A procedure especially suited for obstructive hydrocephalus. It involves the creation of an opening in the floor of the third ventricle to allow CSF drainage.
- Endoscopic Third Ventriculostomy with Choroid Plexus Cauterization (ETV/CPC)

VP shunt insertion may be performed as an elective or emergency procedure depending on the presentation and associated pathology.

Contraindications to shunt placement:

- Infection over the entry site.
- CSF infection.
- Bloody CSF: potential for clots to block the shunt. Initial External Ventricular Drainage (EVD) can be performed to treat raised ICP until it is reasonable to shunt.
- High CSF protein (relative contraindication): can also potentially lead to shunt blockage.
- Coagulopathy (relative contraindication).

Anaesthetic considerations for VP shunt placement

The following must be considered for successful outcome of anaesthesia:

- Coexisting congenital anomalies and syndromes need to be considered when planning anaesthesia.
- Large head may be wobbly and heavy. An assistant or head roll can help to stabilise the head.
- A large head may also prevent optimal positioning for laryngoscopy, thus ramping may be required. A difficult airway tray should be available.
- Risk of airway occlusion from over-flexion of the neck due to large head falling forward.
- Raised ICP: aim to prevent further rise in ICP at induction and intraoperatively.
- Positioning - supine, slight head up and with head tilt, usually left tilt.
- Restricted access to patient intraoperatively requires adequate intravenous access for fluid administration and intubation to secure the airway.

- The patient can be unpleasantly stimulated while the surgeon advances the trocar for tunnelling. Ensure good analgesia/ deep anaesthesia and muscle relaxation prior to tunnelling to avoid stimulation, pain and movement.
- Risk of postoperative nausea and vomiting (PONV) which requires use of antiemetic particularly in children older than 2 years.
- Intraoperative bleeding may be significant especially in small infants and they may require blood transfusion.

Preoperative management

The goals of preoperative anaesthesia management are to establish a rapport with the patient/ parents, allay anxiety, do a proper review of the patient and laboratory investigations, optimise the patient's physical condition if possible and to plan a safe anaesthetic technique.

The child may have coexisting congenital anomalies like congenital heart disease or spinal bifida. Other children may be syndromic (e.g. Down's syndrome). These conditions may have implications for anaesthesia. The cause of the hydrocephalus must be considered when planning anaesthesia. History should include symptoms suggestive of raised ICP such as seizures, vomiting and neurologic deficits, a drug history may reveal the use of anticonvulsants. The child may have had previous surgeries including previous VP shunt insertions and be coming for a revision or reinsertion.

Physical examination with special emphasis on cardiac, respiratory, neurologic and airway examination is performed. The level of consciousness should be determined. The potential for difficult airway and intubation is assessed and adequate preparations made.

Radiological and laboratory investigations listed earlier are reviewed as well as other investigations related to comorbidities e.g. echocardiography for congenital heart disease. Anaemia, dyselectrolytaemia and infections should be treated prior to surgery (this may require blood transfusion if the child is severely anaemic) and the child optimised as best as possible. The parents (and child) must be properly counselled on the procedure (expectations should be managed ideally by the surgical team) and informed consent obtained. The weight of the child may be erroneously high because of the large head. Standard fasting guidelines are communicated to the care-givers. The child should not be fasted for too long as dehydration can complicate anaesthesia. Maintenance intravenous fluids should be commenced preoperatively to prevent hypovolaemia; younger infants may require dextrose-containing IV fluid to prevent hypoglycaemia.

The anaesthetic technique of choice for VP shunt insertion is general anaesthesia with muscle relaxation. The positioning of the patient's head for the surgery makes the airway inaccessible to the anaesthetist intraoperatively, furthermore tunnelling of the VP shunt from the brain to the peritoneum is stimulating and thus requires a still patient.

Intraoperative management

Transportation to theatre should avoid airway occlusion and hypothermia. The head is prevented from falling forward as this can compromise the airway, a chin lift can help solve this. The patient is kept warm and properly covered to prevent hypothermia. This is especially important for the large head because of its increased surface area.

Difficult airway equipment such as laryngeal mask airway, stylette, gum elastic bougie and a video laryngoscope (if available) should be available at induction of anaesthesia.

Basic monitoring (pulse oximetry, continuous electrocardiogram, non-invasive blood pressure, capnography and temperature) is usually sufficient for VP shunt insertion unless the child has a serious condition that requires more advanced monitoring.

Induction technique is based on the peculiarity of each case. Intravenous induction is applicable to patients without suspected difficult airway. Propofol or Thiopentone and rocuronium/ atracurium/vecuronium are appropriate. Ketamine and suxamethonium should ideally be avoided as they cause a rise in ICP. However, in situations with a risk of aspiration at induction, suxamethonium use is appropriate as the rise in ICP is transient. In patients with raised ICP, pre-treatment of suxamethonium can be done with a non-depolarising muscle relaxant. In cases of difficult airway, inhalational induction is preferred using Sevoflurane (or halothane if sevoflurane is unavailable). Mask ventilation may be a challenge because the head can fall forward and occlude the airway therefore proper stabilisation should be ensured using a head roll. Getting a proper mask seal can occasionally be problematic, thus different types and sizes of face masks should be provided. In cases of raised ICP, care should be taken with the use of volatile agents especially halothane, because they increase cerebral blood flow (CBF) which could lead to further rise in ICP. Isoflurane and Sevoflurane are associated with the least increase in CBF, keeping the minimum alveolar concentration (MAC) below 1 also lessens the risk of rise in CBF. Ramping may be required for optimal laryngoscopic view and easier tracheal intubation. Ramping involves placing supports (a ramp) beneath the head, neck and shoulders to bring the ears and sternum to the same horizontal plane/ level. Laryngoscopy and tracheal intubation may sometimes be easier in the lateral position.

Maintenance of anaesthesia is achieved using volatile agent, oxygen and air. Nitrous oxide is avoided as it increases CBF. Total intravenous Anaesthesia can be used in older children.

Normal Saline or Ringer's Lactate is employed for IV fluid maintenance; hypotonic solutions are best avoided to prevent further damage to the brain from cerebral oedema. Fentanyl, paracetamol and diclofenac suppository (in children >10kg) will provide adequate analgesia. Hypercapnia must be prevented as it causes cerebral vasodilatation and increased cerebral blood flow which causes an increase in ICP and resultant reduction in CPP. Prolonged hypocapnia on the other hand causes cerebral vasoconstriction which can lead to ischaemia. Normocapnia is preferred ($ETCO_2$ of 35-45mmHg). The theatre suite should be kept thermo-neutral and the child actively warmed. Adequate antibiotic coverage is necessary to prevent infection.

Positioning is usually supine with a head tilt and slight head up. The surgeon may infiltrate the scalp with local anaesthetic and adrenaline

mixture to reduce blood loss and provide analgesia. The dose of local anaesthetic and adrenaline used must be within safe limits for the child's age and weight. Prior to tunnelling of the shunt from the head down to the neck and abdomen, adequate analgesia and muscle relaxation is ensured. Antiemetic e.g. ondansetron 0.1mg.kg^{-1} may be administered to prevent postoperative nausea and vomiting in older children.

At the end of surgery, the oropharynx is suctioned and residual neuromuscular block antagonised with neostigmine and glycopyrrolate/atropine, or sugammadex. Extubation may be performed following confirmation of return of good muscle function and tidal volume. Extubation should be performed when the child is fully awake.

Postoperative management

In the Post Anaesthesia Care Unit (PACU), the child's head is properly positioned with slight head-up tilt and chin lift to avoid airway occlusion which can lead to hypoxia and cardiac arrest.

Depending on the patient's clinical condition, some children may require direct admission to the ICU, while others may be observed in the PACU and sent to the ward.

Good shunt monitoring is very important for early detection of complications so that they are quickly resolved before the patient deteriorates.

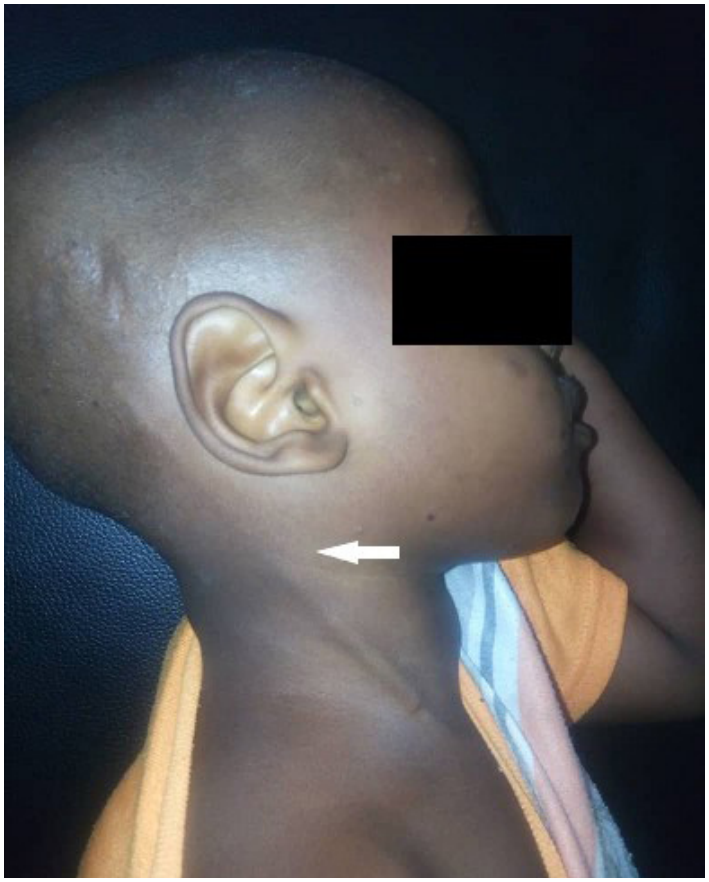

Figure 3: A Right sided Ventriculo-Peritoneal shunt in place. Picture courtesy Dr. M. R. Mahmud, Associate Professor, Ahmadu Bello University, Zaria, Nigeria.

Outcome/ Prognosis

VP shunts can be life-saving; however, the outcome depends on the indication for the shunt. Patients with benign disorders have better outcomes than those with malignant tumours. In children, up to 15 - 50% of VP shunts fail within two years and repeat surgeries are often required.

MENINGOMYELOCELE

Meningomyelocele (Myelomeningocele) is a type of spina bifida that is characterised by the protrusion of the meninges and spinal cord through a vertebral defect into a sac. It occurs due to failure of closure of the neural tube during embryonic development (fourth-week post-fertilization). There are three main types of spina bifida - spina bifida occulta, meningocele and meningomyelocele, with meningomyelocele being the most severe.

The commonest location for meningomyelocele is the lumbosacral region (lower back), though it may rarely occur in the thoracic region and neck. The incidence is 1 in 1000 livebirths, with some geographic variation. It is 3 to 7 times more common in females than males. There is higher prevalence in whites and Hispanics than in blacks. Low socioeconomic status also increases the risk.

Meningomyelocele is a condition with serious neurologic implications. It may occur with other congenital anomalies such as facial clefts, cardiac anomalies and urogenital anomalies. Associated problems include lower limb paresis/ paralysis, bladder or bowel incontinence, Arnold-Chiari malformation, hydrocephalus, a tethered spinal cord and latex allergy.

Causes and Risk factors

The cause of meningomyelocele is still not very clear, but it is associated with nutritional, environmental and genetic factors. A maternal deficiency in folic acid has been demonstrated to play a role in the pathogenesis. Environmental factors such as maternal diabetes mellitus, obesity as well as exposure to folic acid antagonists and anti-

Table 3: Complications of VP shunt insertion

Intra-operative	Post-operative
Bleeding from subcutaneous vessels during the tap	Infection - Shunt infection, ventriculitis, meningitis, peritonitis
Ventricular collapse from rapid aspiration of CSF	Shunt obstruction/ Kinks
Intracranial haemorrhage if CSF is drained too rapidly	Over-drainage, under drainage
CSF leak from puncture site	Shunt failure (from obstruction, infection,shunt component separation or migration, pseudocyst formation, bowel perforation, etc.)
Pneumothorax	Misplaced shunt
Infection from skin flora entering the shunt	Abdominal complications: peritoneal pseudocysts, lost distal catheters, bowel perforations and hernias.

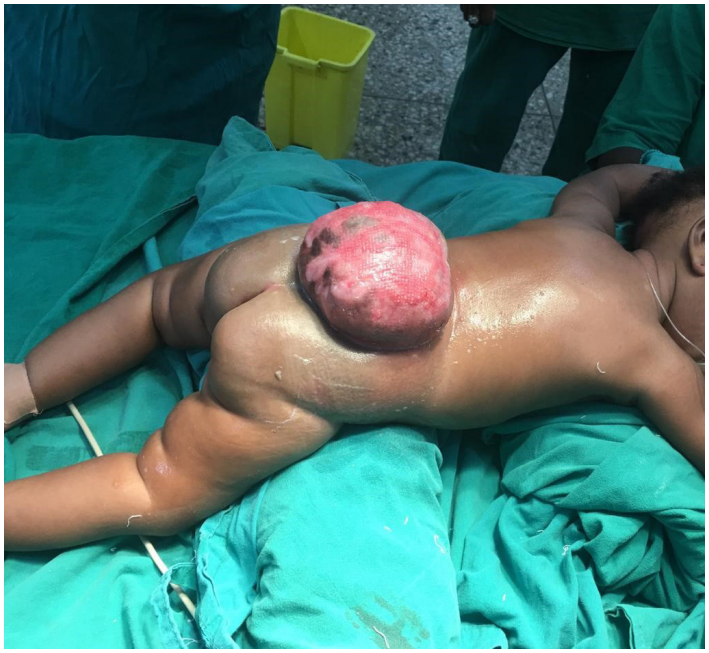

Figure 4: A large lumbosacral meningomyelocele. Picture courtesy of Dr Osazuwa UA, Consultant Neurosurgeon, University of Benin Teaching Hospital, Benin City, Nigeria.

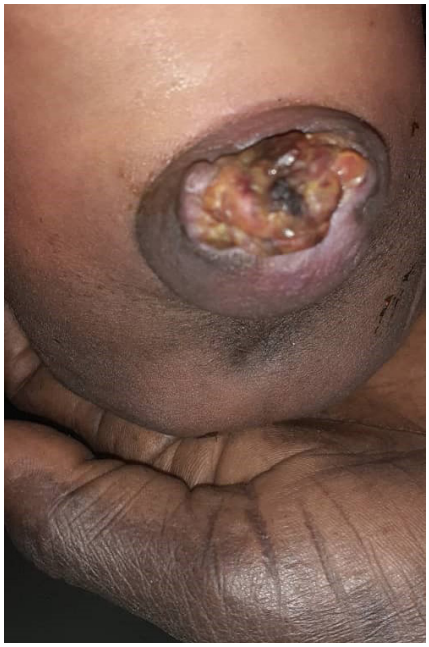

Figure 5: Ruptured meningomyelocele. Picture courtesy of Dr Timothy S, Senior Registrar, Neurosurgery Department, Ahmadu Bello University Teaching Hospital, Zaria, Nigeria.

epileptics like carbamazepine, valproic acid and methotrexate have been implicated.[5,10] Methylenetetrahydrofolate reductase (MTHFR) 677TT genotype is a risk factor for meningomyelocele. There is also increased risk for subsequent babies to have meningomyelocele after an index case in a family.

Clinical features:

The most common presentation of meningomyelocele is a swelling at the back with or without associated features of hydrocephalus, noted at birth or on antenatal ultrasound. The child may also present with lower limb paresis/ paralysis. The presenting neurologic deficits depend on the level of the lesion. When meningomyelocoele is noticed at birth, the neuroplaque is at risk of trauma and subsequent CSF leakage and infection. The sac may be intact or have ruptured at presentation. It should be covered with a warm soaked gauze and the neonate transferred to a specialised centre.

Investigations

Prenatal: Screening for elevated maternal alpha-fetoprotein level during the first trimester is diagnostic in 85% of cases. Amniocentesis can be performed to test for alpha-fetoprotein level. Ultrasound is very effective in screening for neural tube defects.

Postnatal: CT scan, MRI.

Treatment

Surgical repair is the mainstay of treatment of meningomyelocele which involves closure of the neural defect. It is a surgical emergency and primary closure is done within 24 – 48 hours of birth to reduce the risk of rupture of the neuroplaque and further neurological damage.

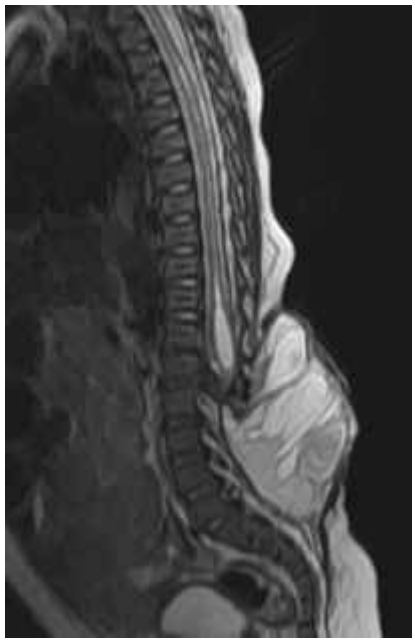

Figure 6: An MRI showing long segment syrinx with meningomyelocele in a child, sac contains nerve roots and CSF. Picture courtesy of Dr Ugwuanyi C, Consultant Neurosurgeon, National Hospital Abuja, Nigeria.

Anaesthetic considerations for meningomyelocele repair

- Prone positioning is required for surgical access
- Protection of meningomyelocoele during induction of anaesthesia requires a doughnut roll or induction in the lateral position.
- Temperature control, avoid excessive heat loss.

- Risk of Latex sensitisation and allergy because of repeated surgical procedures and urethral catheterisations. Where possible, anaesthesia and surgery should be latex-free.

If there is associated hydrocephalus, the anaesthetic considerations will include those already discussed above.

Pre-operative management

The preoperative review and investigations are generally as highlighted earlier for VP shunt.

If rupture of the neuroplaque has occurred, the child may be acutely ill with hypothermia and infection, thus will need resuscitation and optimisation before surgery.

Intra-operative management

Anaesthetic technique of choice is general anaesthesia with tracheal intubation. For surgical access, the child will be placed prone on the operating table. Intravenous or inhalational induction is employed after preoxygenation. Anticholinergic prophylaxis with atropine or glycopyrrolate may be indicated in neonates. Tracheal intubation is done with the patient supine or in lateral position, the tracheal tube must be fixed securely to minimise dislodgement during positioning. In the supine position, the meningomyelocele should be placed in a 'doughnut' to avoid unnecessary pressure on it and accidental rupture. An armoured tracheal tube is ideal to prevent kinking in the prone position, if not available a regular tracheal tube can be used. However, care must be taken to prevent kinking of the tube while in the prone position. The eyes should be well covered by pads and tape to avoid injury in the prone position. A head ring will be required to place the head in a comfortable position and excessive rotation of the head is avoided. All pressure areas are padded and the abdomen ensured to be freely mobile for adequate ventilation and to prevent engorgement of epidural vessels from increased intra-abdominal pressure which increases blood loss. It is imperative to re-confirm correct tracheal tube placement after positioning as it can be easily dislodged. This is reliably done with capnography or auscultation. Fentanyl or remifentanil and paracetamol are adequate for intra-operative analgesia. Volaemic status is maintained to ensure adequate spinal cord perfusion pressure and minimise spinal cord ischaemia. Fluid replacement is with an isotonic solution and 3rd space loss may be high. Blood glucose monitoring is essential. Children with meningomyelocele have defective autonomic control below the lesion and easily become hypothermic. Active warming methods must therefore be deployed.

If the surgeon intends to do direct muscle stimulation to spare neurologic tissue, ultrashort acting muscle relaxants are used. A VP shunt may be inserted if the child has associated hydrocephalus. Blood loss is usually minimal except for large lesions requiring extensive flap cover. In addition, the surgical site may be infiltrated with adrenaline to reduce blood loss in these situations. Local anaesthetic can also be infiltrated at the end of surgery to provide immediate pain relief.

At the end of surgery, the patient is returned to the supine or lateral position for emergence and extubation. Adequate intravascular volume must be ensured before returning to the supine position to prevent hypotension.

Post-operative management

Postoperatively, the child is nursed in the Post Anaesthesia Care Unit, the High Dependency Unit or the Intensive Care Unit depending on perioperative condition. Neonates less than 60 days post-conceptual age have a high risk of post-operative apnoea and should be appropriately monitored. Symptoms of raised ICP can occur post-operatively in patients with associated hydrocephalus if a shunt was not placed. Other immediate post-operative complications include brain stem herniation presenting as bradycardia, apnoea, cyanosis and respiratory arrest.

Meningomyelocele repair can also be done in utero, this will involve general anaesthesia for the mother. Foetal repair has been shown to decrease the need for shunt placement and is associated with better outcomes and less morbidity. However, foetal repairs are presently available only in quaternary health systems with extensive training and resources.

Postoperative complications

- Apnoea
- CSF leakage
- Wound dehiscence
- Infection
- Hydrocephalus/ Raised ICP

Outcome/ Prognosis

Physiotherapy will be required to optimise limb function. Survival rates have improved due to recent advances, however urinary tract infection can still be a problem due to repeated need for catheterisation.

CONCLUSION

Understanding of the pathophysiology of these paediatric neurosurgical conditions help to plan safe anaesthesia in order to prevent worsening of morbidity and also to help improve surgical outcomes.

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Clinical Review

Update in
Anaesthesia

Anaesthesia in children with congenital heart disease for non-cardiac surgery

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Abstract

There is an increasing prevalence of children with congenital heart disease (CHD) presenting for non cardiac surgery due to advances in modern medicine which means more children with CHD are surviving for longer and are thus exposed to the usual illnesses and injuries of childhood. The complex nature of some cardiac lesions, and the frequent association of CHD with other congenital abnormalities means that the perioperative care of these children presents unique challenges for the anaesthetist. This article aims to review the perioperative considerations of children with CHD presenting for non-cardiac surgery. We provide a classification of CHD based on physiology, identify important factors for consideration during risk stratification and discuss an evidence-based approach to perioperative management.

INTRODUCTION

With advances in both diagnostic and interventional medicine, more children with congenital heart disease (CHD) are surviving. In the UK, 1 in every 180 children is born with CHD, and between 2000 and 2010 the number of operations for CHD increased by 80%.[1] This means increasing numbers of children with CHD are presenting for non-cardiac surgery because they are subject to the same range of illness and injuries as other children. Children with CHD present a unique set of challenges and can be a source of anxiety for non-paediatric anaesthetists. A one-size-fits-all approach to anaesthesia is impossible because of the wide spectrum of disorders and varying risk profiles.

This article aims to review the classification of CHD, outline the associated risks, and present an evidence-based approach to the anaesthetic management of children with CHD presenting for non-cardiac surgery.

Limitations: The term CHD is used very broadly and generally includes children born with structurally abnormal hearts, but can also include children born with structurally normal hearts but abnormal electrophysiological pathways causing congenital arrhythmias, for example Wolf-Parkinson White syndrome. Congenital arrhythmias are a separate group of congenital heart diseases with their own unique classifications and treatment pathways, which merit a review of their own. Therefore they are outside the scope of this article and will not be discussed.

CLASSIFICATION OF CHD

Congenital syndromes may also be associated with congenital heart disease and it is important for the anaesthetist to be aware of these syndromes and the cardiac malformations associated with these. For example, children with Down's syndrome commonly present for adenotonsillectomy and 40% of children with Down's syndrome have CHD (most likely ventricular septal defects and atrio-ventricular septal defects).[18] Other examples of congenital syndromes associated with congenital heart disease are discussed in the pre-assessment section of this article.

Children with CHD may be classified anatomically or physiologically. In this article we use a physiological classification based on circulation type. See Table 1.

Normal or 'series' circulation

The normal heart (Figure 1) has two separate circulations: a pulmonary (right sided) and systemic (left side) circulation which work together in series. Examples of CHD with a normal circulation are valvular disorders (for example: aortic stenosis, parachute mitral valve, Ebsteins anomaly) or cardiomyopathies which may be hypertrophic, dilated, restrictive or a combination or one or more types.

Some forms of CHD have a 'normal' circulation but the pulmonary and systemic circulations are not entirely separate, instead mixing of oxygenated and deoxygenated blood occurs through one or more 'holes' (e.g. VSD).

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Table 1: Physiological classification of CHD

Normal Circulation	Balanced/Parallel Circulation	Single Ventricle Circulation
• ASD • VSD • Tetralogy of Fallot • Valvular disorders e.g. AS, Ebstein's anomaly, • Cardiomyopathies • Coarctation of the aorta (CoA)	• Truncus Arteriosus • Transposition of the great arteries • Hypoplastic left heart syndrome • Large unrestricted VSD • Large unrestricted AVSD • Duct dependent lesions such as pulmonary atresia with intact ventricular septum • Children with a BT shunt (if the shunt is large these children will exhibit a balanced circulation)	Children who have had a Glenn or Fontan procedure A Glenn or Fontan procedure may be undertaken for a wide range of underlying conditions but commonly for: • Hypoplastic Left Heart syndrome (HLHS) • Other conditions where there is significant ventricular imbalance such that one of the ventricles would be incapable of maintaining a sufficient output, examples may include: Double Outlet Right Ventricle (DORV) • Pulmonary atresia (PA) with an intact intraventricular septum • Tricuspid Atresia (TA)

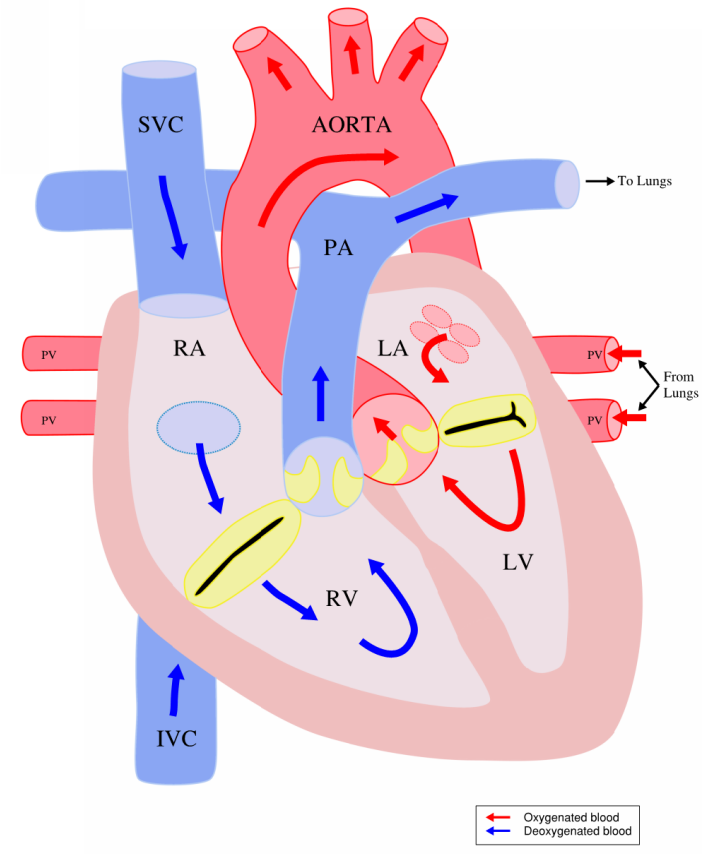

Figure 1: Normal circulation

The direction blood flows through the lesion depends on the pressure gradient and is documented in the echocardiography report as a shunt. Left-to-right shunts result in increased pulmonary blood flow and potentially decreased systemic blood flow; right-to-left shunts cause deoxygenated blood to flow into the systemic circulation, causing cyanosis and reduced pulmonary blood flow.

The direction and amount of shunting depends on the pressure gradient and size of the defect. When the size of the defect is small, this provides a significant resistance and limits the 'shunting' of blood. When the defect is very large, blood may move freely from left-to-right and back again depending on the relative balance between the systemic (SVR) and the pulmonary (PVR) vascular resistance. In this situation infants may exhibit what is known as a 'balanced' circulation physiology – see below. Changes in SVR and PVR as a result of anaesthesia, including the administration of oxygen, have the greatest effect on large, unrestrictive defects i.e. children with 'balanced' circulation (see below).

Parallel or 'balanced' circulation

Instead of the pulmonary and systemic circulations being separate entities working in series, they function physiologically as one entity and behave as parallel circuits. This means that oxygenated and deoxygenated blood mix freely, and the blood flow to the systemic and pulmonary circulation depends on the relative resistance in each circuit. Thus blood flow to the lungs and body is a 'balance' between SVR and PVR, in other words, where the blood goes depends on the ratio of SVR to PVR. This concept is known as Qp:Qs (where 'Q' means flow). A cardiology assessment may report Qp:Qs is 3: 1 which means that 3 times as much blood is flowing to the pulmonary circulation compared with the systemic circulation. Excessive pulmonary blood flow (PBF) causes pulmonary oedema and poor systemic perfusion (which may compromise coronary and splanchnic perfusion) whereas insufficient PBF causes profound cyanosis. The balance is generally high pulmonary flow (resulting in high oxygen saturations, pulmonary oedema, increased work of breathing and risk of high output cardiac failure) and low systemic flow (with associated risks of low diastolic blood pressure and coronary ischemia, and/or poor gastro-intestinal perfusion and necrotising enterocolitis).

Examples of CHD with 'balanced' circulation physiology include large unrepaired unrestricted ventricular septal defects (VSD) (Figure 2), large atrio-ventricular septal defects (AVSD), a modified Blalock-

Taussig (BT) shunt, truncus arteriosus (TA) and hypoplastic left heart syndrome (HLHS). These infants generally have predominantly left-to-right shunt flow because the SVR is higher than the PVR but the circulation is precariously 'balanced' and inducing anaesthesia in these children must be slow and careful to maintain the 'balance': high concentrations of oxygen will increase PBF and reduce systemic perfusion especially coronary artery perfusion; conversely large doses of induction agent reduce SVR causing increased systemic blood flow which compromises PBF and can lead to profound desaturation. These children can be very difficult to manage and liaison with a specialist paediatric cardiac centre is advised.

Single ventricle circulation

Some forms of CHD are not amenable to full anatomical correction i.e. a biventricular repair resulting in a normal 'series' circulation. Therefore these children will be palliated by creating a circulation based upon a single ventricle. The single ventricle pumps oxygenated blood around the body, whilst blood flows passively to the lungs down a pressure gradient. A single ventricle circulation is usually created as a two or three staged process:

Stage 1 (some children): If an infant is very cyanotic due to critically low PBF, they will require augmentation of PBF in the first few days of life, commonly via a BT shunt. A BT shunt consists of a small (3-3.5mm) gortex tube usually positioned between the right subclavian artery (RSCA) and right pulmonary artery (RPA).

Stage 2 (all children): formation of a bidirectional (supplying both right and left lungs) cavopulmonary shunt (BCPS), also known as a Glenn shunt. Usually performed at 3 – 5 months of age, this connects the superior vena cava (SVC) to the right pulmonary artery (RPA).

Any residual BT or other shunts are removed or ligated. The child remains cyanosed following this procedure (oxygen saturations 75-85%).

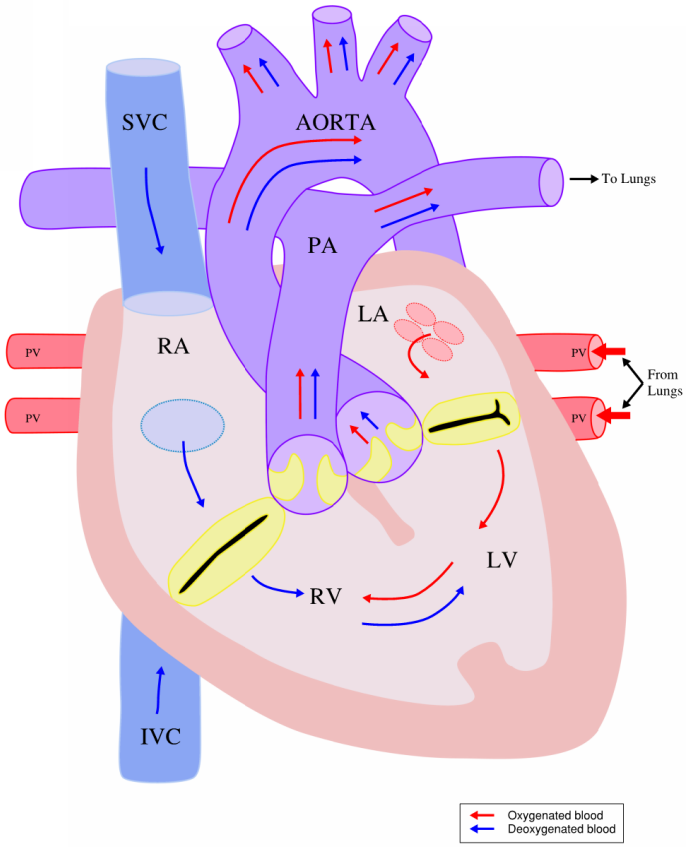

Figure 2: Balanced (or parallel) circulation e.g. large ventricular septal defect

Table 1: Physiological classification of CHD

Balanced/Parallel Circulation	Single Ventricle Circulation
Complexity of CHD	• Single ventricle physiology • Balanced circulation • Cardiomyopathy • Aortic Stenosis
Physiological status of the child e.g. presence of complications of CHD	• Cardiac failure • Pulmonary hypertension • Cyanosis • Arrhythmias
Type of surgery required	• Emergency surgery • Major surgery e.g. intrathoracic, intraperitoneal, vascular reconstructive surgery) • Elective surgery with high risk of major blood loss e.g. (orthopaedic and neurosurgery)
Age of the child	• Under 2 years of age
Hospitalisation of the child before the need for non-cardiac surgery	• Pre-operative hospital stay of 14 days or more

Stage 3 (all suitable children): formation of a total cavopulmonary connection (TCPC) or Fontan circulation (Figure 3). The inferior vena cava (IVC) is connected to the RPA thereby separating the pulmonary and systemic circulation and normalizing arterial oxygenation. This is usually performed between 3 - 5 years of age. The transpulmonary pressure gradient which is from the pulmonary artery (which is under low pressure coming from the superior and inferior vena cava) to the common atrium is now the sole determinant of PBF. The transpulmonary gradient is influenced by volume, pressure, resistance and compliance. Therefore, the single ventricle circulation is very sensitive to increases in volume status of the child, PVR and intrathoracic pressure which can compromise PBF.

This has implications for ventilatory strategy where the pros and cons of spontaneous ventilation versus positive pressure ventilation need to be carefully evaluated. Spontaneous ventilation causes negative intrathoracic pressures thereby improving PBF; positive pressure ventilation may reduce PBF, but does allow greater control of oxygenation and minute ventilation, thus avoiding hypoxia and hypercapnia. Positive end-expiratory pressure should be optimized; and peak inspiratory pressures and inspiratory times minimised to facilitate PBF.

In order to progress to a Fontan circulation certain criteria must be met which include but are not limited to: a low PVR, suitable single ventricular function, and minimal valvular regurgitation. If these criteria are not met then children not suitable for a Fontan may remain 'stuck' at stage 2.

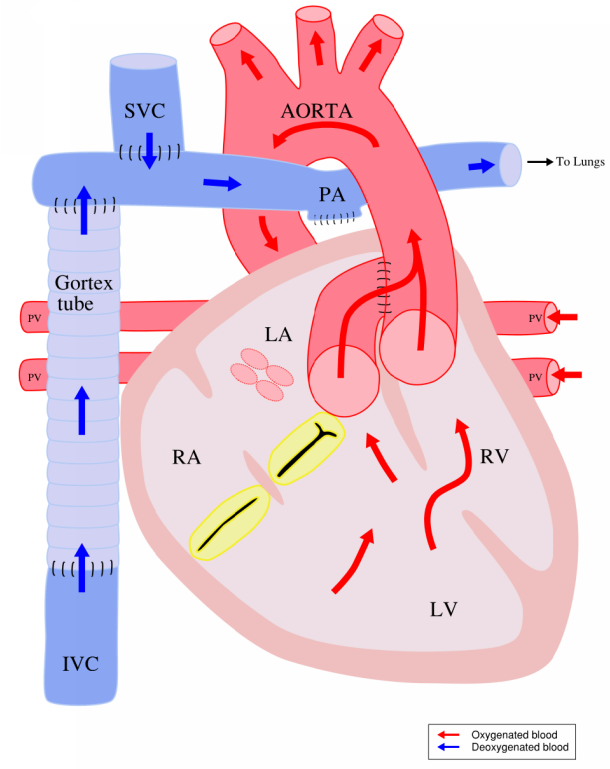

Figure 3: Single ventricle circulation e.g. after total cavopulmonary connection (Fontan) for palliative correction of a double inlet left ventricle lesion with transposition of the great arteries, which is the commonest form of single ventricle.

RISK STRATIFICATION OF CHILDREN WITH CHD UNDERGOING NON-CARDIAC SURGERY

Risk stratification for children with CHD undergoing non-cardiac surgery can be challenging and requires an understanding of the complexity of the cardiac lesion and the functional status of the child at the time of surgery. Some children with corrected CHD lesions have minimal risk of adverse events i.e. similar to children without CHD[2]; while other children with complex CHD are at significant risk of morbidity and mortality when undergoing non-cardiac surgery.[3] The most important risk factors are the complexity of CHD, the physiological status, age, and the type of surgery. The individual risk factors that have been identified are listed in Table 1 and discussed in detail below.

Complexity of heart disease

The following four categories of CHD are associated with a significantly increased risk of adverse perioperative events: single ventricle physiology, balanced circulation physiology, dilated or restrictive cardiomyopathies and aortic stenosis leading to left ventricular outflow tract obstruction. All of these conditions leave the child with significantly limited reserve. Careful risk to benefit analysis should be done prior to proceeding with an anaesthetic/operation in these cases.[2-10, 18]

Physiological Status:

If the child is physiologically well and asymptomatic this conveys a lower risk than children who have developed sequelae leading to poor physiological compensation from their cardiac lesion. The presence of any of the following long-term sequelae of CHD indicate a child is at high risk of perioperative adverse events: cardiac failure, pulmonary hypertension, arrhythmias and cyanosis.

Cardiac Failure

Cardiac failure results from either pressure or volume overload on the heart. Pressure overload may be caused by residual outflow tract obstruction and volume overload may result from ongoing shunts or incompetent valves.[2] Signs and symptoms of cardiac failure should be sought during pre-operative assessment as they have been shown to be associated with a high risk of adverse events during non-cardiac surgery in several studies.[3-7] Signs include sweating, tachypnoea, tachycardia and cool peripheries. In babies signs also include poor feeding, failure to thrive and hepatomegaly. Older children may complain of poor exercise tolerance, and may have signs of chest crackles and failure to gain weight.

The use of pre-operative angiotensin converting enzyme (ACE) inhibitors has been shown to be associated with haemodynamic instability on induction, while the use of pre-operative digoxin and/or inotropes is associated with haemodynamic instability during maintenance of anaesthesia.[8] A recent study by Lee et al[5] of over 3000 patients with congenital heart disease found that any form of depressed ventricular function was a risk factor for requiring inotropes during non-cardiac surgery. Murphy et al also found that 96% of patients with heart failure required inotrope use and 10% suffered cardiac arrest.[9] Given the severity of risk associated with anaesthesia in children with heart failure, we recommend that they are transferred to a specialist centre for even minor surgery.[10] If transfer is not possible, liaison with specialist paediatric cardiology

and paediatric cardiac anaesthesia services is advised. It should be noted that the time taken for both gaseous and intravenous induction will be prolonged and so considerable patience is necessary during induction to avoid excess drug administration.[2] Prolonged use of 8% sevoflurane and propofol may produce a profound decrease in cardiac output meaning that ketamine is generally a preferable option.[11]

Pulmonary Hypertension

Pulmonary hypertension (PHT) is defined as having a pulmonary artery pressure over 25mmHg at rest or 30mmHg on exercise.[2] PHT is a known risk factor for adverse outcomes following non-cardiac surgery.[2-8,12] In a study by Warner et al of 276 patients with CHD, those with a diagnosis of PHT had a higher complication rate (15%) than those with CHD without PHT (4.7%).[12] The pathophysiology and development of pulmonary hypertension varies with different lesions and management is complex and often includes: 100% oxygen, inhaled nitric oxide, intravenous prostacylin, inotropic support of the right ventricle and other measures to maintain cardiac output and pulmonary blood flow (PBF). Therefore if children who are receiving treatment for pulmonary hypertension require surgery, then they should be transferred to a specialist centre where paediatric cardiac intensive care is available.[10]

Cyanosis

Cyanosis is a common feature of unrepaired or palliated CHD. Chronic cyanosis (hypoxaemia) causes changes in the blood composition, coagulation profile, secondary erythrocytosis and hyperviscosity.[13] Altered coagulation is due to thrombocytopenia, decreased von Willebrand factor and a range of clotting factor deficiencies.[13] These haematological changes increase the risk of both thrombosis and infarction, and in children under 5 there is an increased risk of cerebral vein and sinus thrombosis. These risks are increased by dehydration, fever and iron deficiency. Treatment with intravenous fluids (or at a minimum encouraging oral fluid intake) may be initiated preoperatively to minimize these risks, however further treatment should be based on the advice of specialist paediatric haematology and cardiology services.

Arrhythmias

A pre-operative electrocardiogram (ECG) should be reviewed in all children with congenital heart disease. Previous surgery may have affected conduction pathways causing an increased risk of arrhythmias under anaesthesia. Up to 30% of children with single ventricle physiology will die from arrhythmias.[12] The pre-operative ECG may help to predict risk, for example right bundle branch block is common and unlikely to degenerate into complete heart block, while ventricular ectopics (VE's) are a worrying sign and are associated with an increased risk of sudden cardiac death.[12] Therefore, all arrhythmias, especially VE's should be discussed with a paediatric cardiologist and those deemed to be high risk should be transferred to specialist centres where appropriate paediatric cardiology and intensive care support is available.

Type of surgery

Mortality for children with CHD undergoing major surgery is significantly higher (16%) than for minor surgery (3%).[4] Major surgery is defined as intrathoracic, intraperitoneal or vascular reconstructive surgery. Lee et al also found orthopaedic and neurosurgery cases to be associated with higher risk of adverse events.[5] This may be because the commonest cause of cardiac arrest in non-cardiac surgery was due to hypovolaemia[14,15] and therefore if there is a risk of major haemorrhage from the surgery, this increases the risk of adverse events.

Other risk factors

Age: In a review of 372 cases with a background of CHD who had a cardiac arrest, 47% occurred in those less than 6 months of age and 70% occurred in those less than 2 years.[16] Other studies also identified young age as a risk factor for adverse events in those with CHD undergoing non-cardiac surgery.[6-7,14]

Pre-op Length of Stay: In a study by Watkins et al, in 145 patients with a preoperative stay >14 days (without intubation) 12.4% required mechanical ventilation post operatively, postoperative length of stay was also longer in those with a preoperative length of stay >14 days.[8]

Other: higher ASA physical status, birth at a tertiary centre (indicating co-existing morbidity or complexity of CHD), and emergency surgery are also independent risk factors for adverse perioperative events in children with CHD undergoing non-cardiac surgery.[2-9]

ANAESTHETIC MANAGEMENT

Pre-operative Assessment

Meticulous preparation and good communication with the multi-disciplinary team including the surgeon and the child's paediatric cardiologist are crucial to ensuring safe delivery of care. If the child presents to a non-specialist centre this may involve communication with several different hospitals. We suggest careful attention is paid to the following factors during pre-operative assessment:

a) Review the cardiac lesion and type of circulation. This should be done by looking at the child's latest cardiology letter, echocardiography (ECHO) report and ECG. Decide if the child is at high risk of adverse events during surgery and therefore requires transfer to a specialist centre.

Based on the evidence-based risk classification described above (Table 1), we suggest the following guidelines for consideration of transfer to a specialist centre. However, the availability of local services and expertise means that decisions will ultimately need to be made on a case-by-case basis:

- Elective Surgery:

High risk: Transfer to a specialist centre

Intermediate risk: Consider transfer to specialist centre: discuss between local team and specialist centre and if required the transfer team

Low risk: Manage in local hospital.

- Emergency Surgery

High and Intermediate risk: Discuss with specialist centre and transfer team whether a time critical transfer is possible. If this is not an option, seek advice from the specialist centres' surgical, anaesthetic and cardiology team regarding perioperative management.

Table 1: Factors affecting pulmonary and systemic vascular resistance

Increased PVR	**Decreased SVR**
Hypoxia, hypercarbia, acidosis, hyperinflation, high PEEP, increased haematocrit	Pyrexia, some induction agents e.g. propofol, general anaesthesia, sympathetic blocks e.g. epidural, spinal
Decreased PVR	**Increased SVR**
High FiO_2, hypocarbia, alkalosis, decreased haematocrit	hypothermia, vasoconstrictors, sympathetic stimulation e.g. pain

Low risk: Manage in local centre, if concerned contact specialist centre for advice.[17]

b) Review the child's latest ECHO report and:

i. Assess if there are any 'holes' in the heart through which shunting can occur. If so, which way is the blood shunting? Think through the physiology of the shunt: will changes to the SVR or PVR have haemodynamic consequences under anaesthesia? Are the oxygen saturations measured appropriate for the type of lesion present?

Also if there are any 'holes' through which shunting can occur, be very careful with air bubbles when injecting fluid / medication because of the risk of air emboli passing from the venous to systemic circulation through the 'hole' and causing arterial cerebrovascular air emboli.

ii. Assess if there is any left or right ventricular outflow tract obstruction. If so, think through the physiological response of the obstruction to changes in SVR and PVR under anaesthesia.

c) Does the child have chronic cyanosis? In these children it is important to avoid dehydration and consideration should be given to minimizing starvation times and the use of intravenous preoperative hydration.

d) Are there any signs of recent upper or lower respiratory tract infections: this may affect airway reactivity and PVR, as management of PVR is central to the perioperative management of children with CHD especially those with single ventricle physiology as mentioned below.[17]

e) Does the child have another associated abnormality/dysmorphic features? Recognisable chromosomal abnormalities are seen in 25% of children with CHD. Children with Trisomy 21 (Down's syndrome) may also have an AVSD or VSD, those with DiGeorge Syndrome (22q11 deletion) may show aortic arch abnormalities, VSD, those with Marfan's syndrome may suffer from aortic root dilatation and dissection, those with Goldenhar syndrome or VACTERL (a syndrome consisting of Verterbral, Ano-rectal, Cardiac, Trachea-Eosophageal, Radial and Limb abnormalities) association may have a VSD or tetralogy of Fallot and those with Apert syndrome may have pulmonary stenosis or a VSD.[18]

f) Premedication: sedative premedication may be beneficial as this can help with anxiolysis, therefore avoiding catecholamine release, which cause tachycardia (thereby worsening any right or left sided stenotic lesion), increase oxygen consumption (which can worsen cyanosis). Premedication may also reduce the amount of induction agent required therefore minimizing the reduction in SVR associated with induction of anaesthesia.

g) Venous Access: may be challenging in children who are on diuretics, or who have had multiple procedures, involving peripheral and central venous catheterisation and arterial catheterisation.

h) Does the child require endocarditis prophylaxis for the procedure? The most recent recommendations from the NICE 2008 guidelines 'Prophylaxis against infective endocarditis' recommends that those at risk of infective endocarditis include those with

- valve replacements,
- structural congenital heart disease, including surgically corrected or palliated structural conditions, but excluding isolated ASD, Fully repaired VSD or fully repaired PDA, and endothelialised closure devices.
- Previous infective endocarditis
- Hypertrophic cardiomyopathy[19]

Specific Anaesthetic Management

There are several techniques described for anaesthetising children with CHD, however, there is no strong evidence to recommend one technique over another. It is advisable to consider which factors affect pulmonary and systemic blood flow (Table 3) and consider the cardiac lesion present. Due to the complexity of some children with congenital heart disease, it may be advisable to have a second consultant anaesthetist or an experienced senior trainee present for induction.

Gaseous induction with sevoflurane can be used safely in children with CHD and may be necessary due to challenging venous access. However, it is important to avoid prolonged exposure to 8% sevoflurane as this will cause a drop in SVR leading to decreased myocardial perfusion and contractility.[17] In those with trisomy[21] gaseous induction should be used with caution as bradyarrhythmias may occur.[20]

Propofol and ketamine are the most studied intravenous induction agents. Propofol produces a significant drop in SVR and mean arterial pressure (MAP). In children with right to left shunts, even a normal induction dose of propofol may increase the right to left shunt fraction causing reduced pulmonary blood flow and therefore decreased oxygen saturations.[11] Ketamine has minimal effect of SVR, PVR, MAP and PAP which makes it an ideal choice for many children with complex CHD and especially in those for whom the anaesthetist must avoid dropping the SVR.

Both isoflurane and sevoflurane are commonly used for maintenance of anaesthesia as they have little effect on shunt fraction[21] or cardiac contractility.[22] The effects of desflurane in children with CHD are less well known. Propofol infusions are likely to cause a reduction

in SVR and risk propofol related infusion syndrome, therefore they may be better avoided.

Opioid infusions and regional anaesthesia have all been successfully used[23,24] and therefore we suggest that the anaesthetist uses their preferred method of analgesia for the type of procedure being undertaken. As is the case in all children, spinal and epidural techniques may cause hypotension and the use of small doses of a vasopressor such as phenylephrine may be needed. In cases where reductions in SVR may be deleterious, the anaesthetist should be ready to treat hypotension promptly.

The use of invasive monitoring (central venous pressure monitoring and invasive arterial blood pressure monitoring) should be guided by the risk stratification: the higher the risk, the greater the need for invasive monitoring to allow inotrope delivery, intracardiac measurements and continuous blood pressure monitoring. However, less invasive monitoring such a near-infrared spectroscopy (NIRS), urinary catheters, intermittent capillary blood gas and lactate measurements also provide useful information of end organ perfusion and may be used as surrogates for tissue perfusion and adequate cardiac output either alone or in combination with invasive monitoring depending on the risk stratification.

SUMMARY

Anaesthesia for children with congenital heart disease for non-cardiac surgery requires a comprehensive understanding of the child's cardiac lesion and pathophysiology. Children with complex CHD (balanced or single ventricle circulation, aortic stenosis and cardiomyopathy) and poor physiological status are at the highest risk of perioperative morbidity and mortality. Poor physiological status is indicated by the presence of pulmonary hypertension, cardiac failure, arrhythmias and cyanosis. Other groups at high risk are children who are less than 2 years old, and those who require emergency surgery, or have been in hospital for over 12 days pre-operatively. High risk children for non-cardiac surgery should be transferred to a specialist centre whenever possible. Children at low to intermediate risk undergoing elective surgery may, depending on the locally available facilities and expertise, be operated on at the local hospital. Thorough pre-operative assessment, good communication with the multi-disciplinary team, both locally and at the specialist centre, and an awareness of the complications which may occur is essential for anaesthetising children with CHD for non-cardiac surgery.

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Update in
Anaesthesia

Anaesthesia for large Wilms' tumour (nephroblastoma)

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Abstract

Wilms' tumour (nephroblastoma) is the most common childhood intra-abdominal malignancy. It may grow very large with late presentation in resource poor settings. Anaesthesia for surgical removal of this tumour requires a good knowledge of the patient: size of tumour, extent of tumour spread, treatment so far, current medications,associated syndromes or co-existing diseases and present physical condition.Intraoperative haemodynamic instability, large fluid shifts and massive blood loss may occur. Safe anaesthesia requires adequate preparation, optimisation and vigilant intraoperative monitoring.

Key words: Wilms' tumour, nephroblastoma, intra-abdominal tumour, paediatric anaesthesia, childhood malignancy

INTRODUCTION

Abdominal tumours in children are mostly benign and originate from the kidney. Wilms' tumour also known as Nephroblastoma, is the most common childhood abdominal malignancy with an incidence of 5 – 7% of all childhood tumours and 90% of renal cancers. It is commoner in Blacks with an incidence of 10 cases per million person years than Caucasians (6-9 cases per million person years) and is least seen in Asians (3-4 cases per million person years). There are approximately 500 new cases of Nephroblastoma in the United States of America yearly.

The Male: Female ratio of incidence varies worldwide, with 1:1[1-2]. documented in developed countries. However some African countries have recorded equal rates in boys and girls and even higher rates in boys. It has a peak presentation within the first 4 years of life. Wilms' tumour most commonly affects one kidney, but can occur in both kidneys at the same time. It is very responsive to treatment.

There are no known definitive causes, lifestyle or environmental factors related to the development of Wilms' tumour. It has however been associated with chromosomal and genetic dysfunction; changes in or loss of the WT1 or WT[2] genes (tumour suppressor genes on chromosome 11), change in WTX (a tumour suppressor gene) found on the X chromosome and alteration of CTNNB1 on chromosome 3.

Presentation

The most common presenting signs and symptoms of Wilms' tumour are: Abdominal mass or swelling (60 - 80 %), Hypertension (50%), Abdominal pain (25 %), Fever (5 -30 %), Haematuria (25 %) and dysuria.

Other symptoms are: Nausea, loss of appetite, dyspnoea, varicocele and constipation.

Risk Factors

Risk factors associated with the development of Wilms' tumour are shown in Table 1.

DIFFERENTIAL DIAGNOSIS OF WILMS' TUMOUR

The most common differential of Wilms' tumour is Neuroblastoma which is a tumour of the adrenal glands. Others are:

Benign

- Multicystic kidneys
- Haematomas
- Hydronephrosis
- Congenital gut duplications
- Renal vein thrombosis
- Renal abscess
- Renal rhabdoid tumour

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Table 1: Risk factors associated with Wilms' tumour

Demography	Age (3-4 years) Gender - Female Race - Black
Positive Family history (1 - 2 % of cases)	
Genetic syndromes	WAGR (Wilms' tumour, Aniridia, Genitourinary tract abnormalities and Mental Retardation) syndrome. Associated with 30% to 50% chance of having a Wilms' tumour. Children with WAGR tend to get Wilms' tumour at an earlier age and in both kidneys. Denys-Drash syndrome Frasier syndrome Beckwith-Wiedemann syndrome Perlman syndrome Sotos syndrome Simpson-Golabi-Behmel syndrome Bloom syndrome Li-Fraumeni syndrome Trisomy 18.
Birth defects	Hypospadias Cryptorchidism Aniridia Hemihypertrophy

Malignant

- Fibrosarcoma
- Rhabdomyosarcoma
- Adrenal carcinoma
- Renal cell carcinoma
- Clear cell sarcoma
- Hepatoblastoma
- Hemangiopericytoma
- Non-Hodgkin lymphoma
- Malignant neurogenic tumour.

INVESTIGATIONS/ DIAGNOSIS

Investigations are targeted at making a diagnosis and staging the disease in order to guide surgery/ radiotherapy and to review success after treatment.

Relevant investigations include:

- Abdominal Ultrasound (sonogram) locates the tumour and shows spread to nearby vessels.
- Computed Tomography (CT, CAT) scan locates the tumour, maps its spread into major vessels & other organs such as the lungs.
- Magnetic Resonance Imaging (MRI) scan detects growth of the tumour into major vessels (renal vein and inferior vena cava) and spread to the brain and spinal cord.
- Chest X-ray determines the spread of Wilms' tumour to the lungs and is useful as a baseline for future comparisons of chest x-rays.
- Renal biopsy involves an incisional or excisional biopsy for histological diagnosis and to determine if the tumour is favourable or anaplastic. Most often it is preferable to excise the tumour without prior incisional biopsy.
- Laboratory tests - Full Blood Count (Complete Blood Count) may show anaemia especially in protracted cases; Electrolytes/ urea/ creatinine may show elevated potassium, urea or creatinine levels in renal function impairment or chronic disease; Potassium levels may also be elevated as a result of tumour lysis during chemotherapy.
- Urinalysis may show haematuria. Urinary catecholamines are tested to rule out neuroblastoma.

- Clotting profile is indicated to rule out coagulation problems that may arise from chemotherapy medication or the tumour itself.
- Echocardiography may be requested to check for tumour spread to the heart and to excludecardiomyopathy from chemotherapy.

TYPES/ HISTOPATHOLOGY

Nephroblastoma can be divided into 2 types based on histology.

- *Favourable Histology*: Generally has better prognosis. 90% of cases have favourable histology.
- *Unfavourable/ Anaplastic Histology*: Generally associated with poorer outcomes and requires more aggressive treatment.

A summary of NWTS classification is as follows

Stage	Description
1	Tumour limited to kidney and is completely excised
2	Tumour extends beyond kidney but is completely excised
3	Residual non-haematogenous tumour confined to abdomen
4	Haematogenous or lymph node metastases
5	Bilateral renal involvement

STAGING OF WILMS' TUMOUR

There are various staging systems employed for Nephroblastoma. Staging is determined using imaging studies like CT scan and MRI, staging is also based on surgical and pathological evaluation of the tumour. Radiological tests help to determine if the tumour is resectable or extensive. If the tumour is staged as unresectable, chemotherapy results in reduction of tumour size and vascularity making the tumour easier to handle at a later surgery.

The two most common systems employed are the National Wilms' Tumour Study (NWTS) staging system and the Societe Internationale D'oncologie Pediatrique (SIOP) staging system.

STAGING OF TREATMENT OF WILMS' TUMOUR

The treatment of Wilms' tumour involves chemotherapy, surgery and radiotherapy. Surgery comprises a trans-peritoneal radical nephrectomy. The timing of surgery depends on the treatment protocol selected or adopted in the treatment centre.

The NWTS Group protocol advocates primary surgery for Stages 1 to 3 and then chemotherapy. Stages 4 and 5 undergo neoadjuvant chemotherapy and then surgery after tumour reduction. For Stages 1 to 3 of the SIOP protocol, preoperative chemotherapy is given for 4 weeks and surgery done in week 5. Radiotherapy is done for stages 3 and 4 if the histology is favourable.

ANAESTHESIA CONSIDERATIONS

In the management of Wilms' tumour, anaesthesia may sometimes be required for imaging such as MRI in uncooperative or very young children. Anaesthesia for resection of a nephroblastoma involves the consideration and management of the following which may have an adverse effect on outcome:

- Preoperative hypertension
- Preoperative anaemia
- Hyperkalaemia from tumour lysis (this can be worsened by the administration of suxamethonium and should be corrected before surgery).
- Anaesthesia drugs which can compromise renal function.
- Prolonged abdominal surgery lasting 3- 6 hours.
- Large intra-abdominal mass requiring rapid sequence induction
- Intraoperative haemodynamic instability
- Large fluid shifts and massive blood loss
- Intermittent inferior vena cava (IVC) compression
- Intravascular tumour extension or embolisation

Preoperative Anaesthetic Management

The preoperative management of a child scheduled for nephrectomy for Wilms' tumour involves a detailed review of the patient to establish rapport with the child and parents who would be undoubtedly anxious. If the child has had several sessions of chemotherapy adequate psychological support would be required. This is also the time to discuss with the parents and obtain consent for the anaesthetic technique and pain management options, guide on preoperative fasting and allay anxiety.

Table 2: Chemotherapy agents and their side-effects relevant to Anaesthesia

Chemotherapy Agents	Side effects	Relevant additional Investigations
Actinomyocin	Coagulopathy	Clotting profile
	Hepatic dysfunction	Liver function tests
	Immunosuppression	
	GIT disturbances	Electrolytes
Vincristine	SIADH	Urine & serum osmolality, urinary sodium
	Peripheral neuropathy	
Doxorubicin	Cardiomyopathy	Echocardiography
	Arrhythmias	ECG

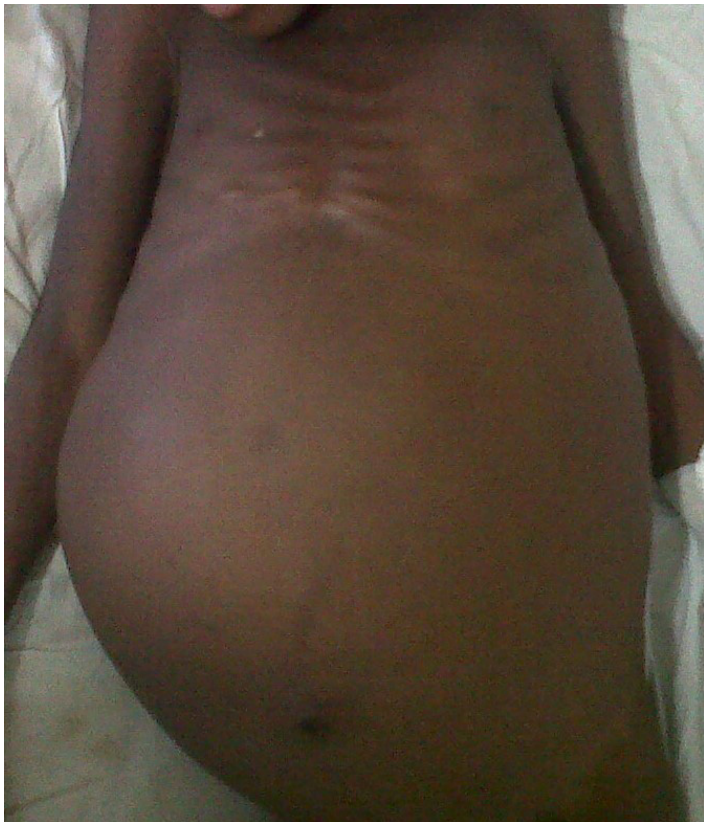

Figure 1: An 8 year old male with huge right-sided nephroblastoma

The history should review the symptoms, disease progression and obtain information on past exposure to anaesthesia and blood transfusion as well as any allergies. Cardiac disease especially congenital heart disease which may co-exist with nephroblastoma should be sought. Large proportions of children with nephroblastoma have co-existing hypertension and will be on an angiotension-converting enzyme inhibitor. With large tumours the child may present with orthopnoea. Since some of the children may be syndromic, it is important to note any syndromes with the associated features and determine possible anaesthetic implications. Details of previous chemotherapy are sought and their side-effects investigated as they may have relevance to the anaesthesia management.

The physical examination will reveal a distended abdomen which may compromise respiration resulting in tachypnoea and dyspnoea. There may be signs of bilateral atelectasis and pneumonia as well as hypertension and tachycardia. Sometimes the child is cachectic due to late presentation with nausea and loss of appetite. Anaemia and difficult venous access as a result of previous multiple chemotherapy sessions may be present. In syndromic children, macroglossia or micrognathia elicited during airway assessment require special attention and preparation for intubation.

Investigations should include a Full Blood Count, Electrolytes, Urea and Creatinine, and a clotting profile including Liver Function Tests. Anaemia and coagulation abnormalities occur due to tumour bleeding or chemotherapy, anaemia may also result from malnutrition. Electrolytes and urea may show some abnormalities as described earlier. Calcium and albumin may be low in advanced stage and in malnourished children.

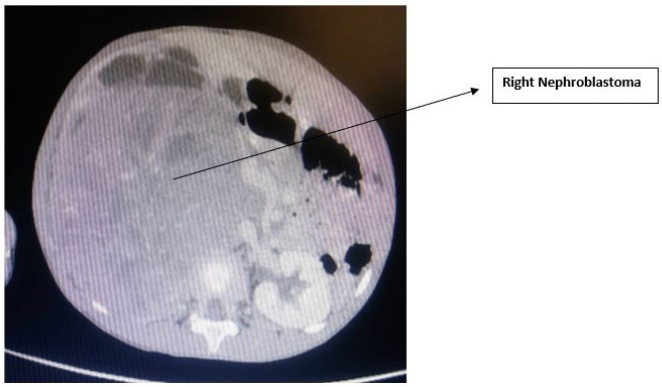

Figure 2: CT showing Right Nephroblastoma: A huge mixed density mass in the right renal region showing characteristic density areas suggestive of dilated calyces. The bowel loops are displaced to the left. The left kidney appears normal with prompt contrast uptake.

Other pre-operative work-up ordered by the surgeon like abdominal ultrasound, abdominal CT, MRI and intravenous urogram should be reviewed as they assess extent of local tumour invasion and help to plan for surgery. A chest x-ray, CT scan and echocardiogram assess tumour spread to lungs, IVC, thoracic vena cava or the heart.

Surgery for excision of a large abdominal tumour has the potential for extensive blood loss and adequate blood must be cross-matched for surgery. In addition, fresh frozen plasma (FFP) may be required. Electrolyte derangements, anaemia and coagulation abnormalities are corrected before surgery.

Consent/ Fasting guidelines: Consent for General anaesthesia and any other anaesthesia intervention including blood transfusion should be obtained. Standard fasting guidelines are ensured before induction of anaesthesia.

Intraoperative Anaesthetic Management

Monitoring: Standard monitoring as for any major abdominal surgery is indicated. This includes pulse oximetry, continuous electrocardiography (ECG), end-tidal Carbon dioxide ($ETCO_2$), non-invasive blood pressure (NIBP), core temperature, hourly urine output and blood loss. Where available, invasive blood pressure (IBP) and central venous pressure (CVP) monitoring are useful as haemodynamic instability may occur with induction, laryngoscopy and tumour manipulation.

Induction: The child is treated as a full stomach as the mass would have displaced the stomach upward. There is therefore a risk of regurgitation and aspiration. If a nasogastric tube is in place, this should be suctioned before induction to reduce gastric content.

After insertion of a large bore cannula, ensure good intravascular fluid volume prior to induction by giving intravenous (IV) Ringer's lactate or Normal Saline, $10ml.kg^{-1}$ (if required) and ascertain adequate output of clear non-concentrated urine. A rapid sequence induction is performed with propofol or thiopentone and suxamethonium utilised for intubation after adequate pre-oxygenation.Thiopentone should be used with caution in cases of renal compromise. Rocuronium may be used in place of suxamethonium if available. Poorly hydrated patients may develop severe hypotension at induction. Ketamine

may be more suitable in the child with haemodynamic compromise. Cricoid pressure should be utilised to reduce the risk of aspiration. Endotracheal intubation is necessary using appropriate sized cuffed tracheal tube. When the abdominal mass is very large with symptoms of diaphragmatic splinting, the child should be induced in the reverse trendelenburg position to improve the compromised Functional Residual Capacity (FRC). Some syndromic patients may have a difficult airway; this should have been anticipated in the pre-operative assessment and prepared for appropriately. Laryngoscopy may result in exaggerated hypertension in patients with pre-operative hypertension, which can be obtunded with the use of IV fentanyl or lidocaine.

Following induction, a central line for fluid administration and CVP monitoring as well as an intra-arterial line for direct blood pressure monitoring and sampling of arterial blood gases are inserted. If a central line is not available, ensure at least 2 wide bore peripheral lines are in place before commencement of surgery as there may be sudden and severe blood loss during tumour resection.

Placement of an epidural catheter will facilitate good intraoperative and post-operative pain management as pain from this surgery is significant. An epidural reduces the stress response to surgery. A one-shot caudal to a mid-thoracic level is beneficial in the absence of an epidural. In siting an epidural, administration of less volume of local anaesthetic should be considered as the epidural space is reduced in the presence of large intra-abdominal masses. The coagulation status of the child must be normal before a central neural block is performed.

Maintenance: A rolled pad or sandbag is placed under the patient in supine position on the side of the tumour to make surgical access easier. Muscle relaxation is essential as it provides good access for the surgery. This can be achieved with most muscle relaxants. Pancuronium is sympathomimetic and undergoes significant renal excretion and is not recommended if pre-operative hypertension or renal impairment exists. Ventilation may become difficult with cephalad retraction during surgery, airway pressure should thus be adequately monitored. Anaesthesia is maintained with volatile agents, halothane may worsen arrhythmias and hypotension and so should be avoided if possible.

Large intraoperative evaporative fluid losses are expected and intravenous fluids using Ringer's Lactate or Normal Saline are employed as maintenance dose fluids. Third space losses may be as high as 10 - 15ml.kg^{-1} per hour and are replaced by crystalloids. Colloid administration may also be indicated. Adequate hourly urine output (at least 1ml.kg^{-1}) is a sign of good volume replacement and organ perfusion. It also helps to preserve renal function. Blood glucose should be monitored hourly and corrected as required. Blood loss can be extensive and all blood transfused should be warmed. Blood replacement should commence at 10% loss of blood volume or earlier depending on preoperative haemoglobin. With massive blood transfusion, FFP may also be required (10 - 20ml.kg^{-1})

The large open abdominal cavity produces significant heat loss and hypothermia. A thermoneutral theatre environment should be created and all fluids and blood warmed before use. It is important for the patient to be actively warmed using a warming mat or forced air warming device. Where these are not available, a simple plastic covering is employed.

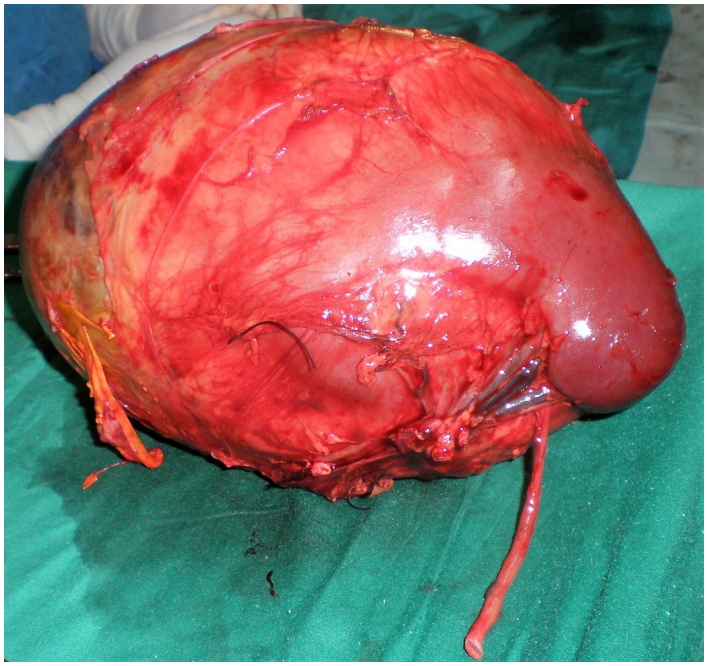

Figure 3: Nephroblastoma measuring 30cm x 24cm after resection.

Adequate intraoperative analgesia should be ensured. This can be provided with intravenous opioids like morphine, fentanyl or remifentanil in addition to paracetamol. Morphine is avoided where renal compromise exists because of the accumulation of its renally excreted active metabolites. Bolus or continuous infusion of local anaesthetic with fentanyl via an epidural catheter is ideal.

Antiemetics such as IV Dexamethasone 0.1mg.kg^{-1} and IV Ondansetron 0.1mg.kg^{-1+} are recommended to prevent postoperative nausea and vomiting.

Emergence: At the end of surgery, skin infiltration of surgical incision site with 0.125% -0.25% plain bupivacaine is done if no epidural catheter was placed. The oropharynx is suctioned and residual neuromuscular block antagonised with neostigmine and atropine or glycopyrrolate. Awake extubation is performed when there are signs of good respiratory effort and muscle function.

Postoperative Anaesthetic Management

Based on the patient's preoperative state, intraoperative findings and blood loss, the patient is nursed in the Post Anaesthesia Care Unit, High Dependency Unit or Intensive Care Unit. Post-operative ventilation may be required in cases of prolonged surgery, massive blood loss, tumour embolization or significant pre-operative atelectasis. Monitoring of cardiovascular parameters is vital as secondary haemorrhage may occur because of the vascular nature of the tumour dissection.

Optimal post-operative pain management is essential for patient comfort and encourages deep breathing thereby minimising the development of post-operative atelectasis and pneumonia. Post-operative pain management may be done via epidural analgesia or by using opioids and paracetamol.

Close monitoring of blood glucose and patient vital signs should be continued.

OUTCOME/ PROGNOSIS

The prognosis for Wilms' tumour and abdominal tumours in general, depends on the stage at presentation, histological type, weight of the tumour and age of the patient. In developed countries where early detection and treatment occur and where there are available medications and standard treatment options, the 5 year survival rate for nephroblastoma is about 80 - 90%. In low- and middle-income countries, prognosis or outcome is usually not as good as patients present late in the disease and treatment becomes more complicated and dangerous or ineffective. Abandonment of treatment is also a problem. Furthermore, radiotherapy and the required medications may be unavailable or irregular in supply. A 5-year survival rate of 31.2% was quoted in a study done in Lagos, Nigeria. Other African studies show a survival rate of 25 to 49 - 1%.

Emerging surgical concepts like nephron-sparing surgery (NSS) and minimally invasive surgical techniques in select groups of patients may help to preserve functional renal units and improve long term morbidity and renal function.

CONCLUSION

The treatment of Nephroblastoma has come a long way with improved survival due to better treatment guidelines. Surgery is a key aspect of this treatment and anaesthetic management involves careful consideration of all the components of this malignancy. The anaesthetist must ensure sufficient patient optimisation though this may sometimes be challenging and time-bound, and be prepared to handle critical stages intra- and postoperatively for a successful outcome.

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Update in
Anaesthesia

Anaesthesia for cerebral palsy

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Abstract

Cerebral palsy is a heterogeneous condition that places a significant global burden on healthcare resources. There are multiple aetiological processes that lead to neurological damage before, during or after birth. Treatment options are many and individualised management plans focused on relieving suffering and improving function should be the mainstay of treatment. The anaesthetist must be aware of key aspects of the condition that may be particularly challenging such as communication, pain control and respiratory compromise. Thorough preoperative assessment and planning including discussion with family members will help the team to provide the best healthcare possible.

INTRODUCTION

The burden of chronic neurodisability in infants and children across the world is significant. In higher income countries an increasing proportion of such cases are related to advances in survival rates in premature and acutely unwell neonates; in lower resource settings, a higher percentage may be related to continued limited access to obstetric and paediatric care and a lack of public health infrastructure. This article will focus on cerebral palsy (CP), a relatively common neurological condition, although aspects of this article are relevant to the management of chronic neurodisabilities of other aetiology.

CLASSIFICATION

Cerebral palsy is a term used to describe a group of conditions characterised by permanent, non progressive motor dysfunction which affects muscle tone, posture and movement. It can be classified in a variety of ways. Traditionally, we identify the motor or movement component and the orientation of limb involvement as shown in Table 1.

In addition to this, current best practice is to determine and document the patients functional status, this being a more useful indicator of their daily activities and the support they may need during their hospital stay. An example of this is the Gross Motor Function Classification System (GMFCS) which grades patients from I to V depending on their functional abilities (see Figure 1). To illustrate its use, if we note that a patient has bilateral lower limb spasticity, one cannot tell from this description whether the child mobilises independently without walking aids or is wheel chair bound.

Table 1: Classification of Cerebral Palsy[1]

Type	Characteristics	Notes
Spastic (70% of patients) Motor cortex / pyramidal tract lesion	Increased muscle tone	Quadriplegic (4 limbs), diplegic (both legs), hemiplegic (one side of body), monoplegic (1 limb)
Dyskinetic (Dystonia, Athetosis, Chorea) – Basal ganglia lesion	Variable tone and activity, repetitive movements	
Ataxic – cerebellar lesion	Loss of coordination and balance, tremor	
Mixed	Mixture of the above	

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Case study 1

An 11 year old, 18kg female with quadriplegic CP and severe cognitive impairment is scheduled for pelvic and femoral osteotomies. A review of her notes and discussion with her parents reveal:

- Communication is limited to single words. She has poor vision and hearing. Anticipated difficulty in assessing pain
- Regular seizures despite administration of anti-epileptic medication
- Excessive drooling and is fed via a percutaneous endoscopic gastrostomy (PEG) feeding tube.
- 2-3 lower respiratory tract infections per year, usually during winter
- Upper and lower limb contractures, wheel chair bound

This case is clearly complex and poses multiple challenges to the surgical and anaesthetic team. For a favourable outcome, careful planning is needed in the pre, intra and post operative period.

Case study 2

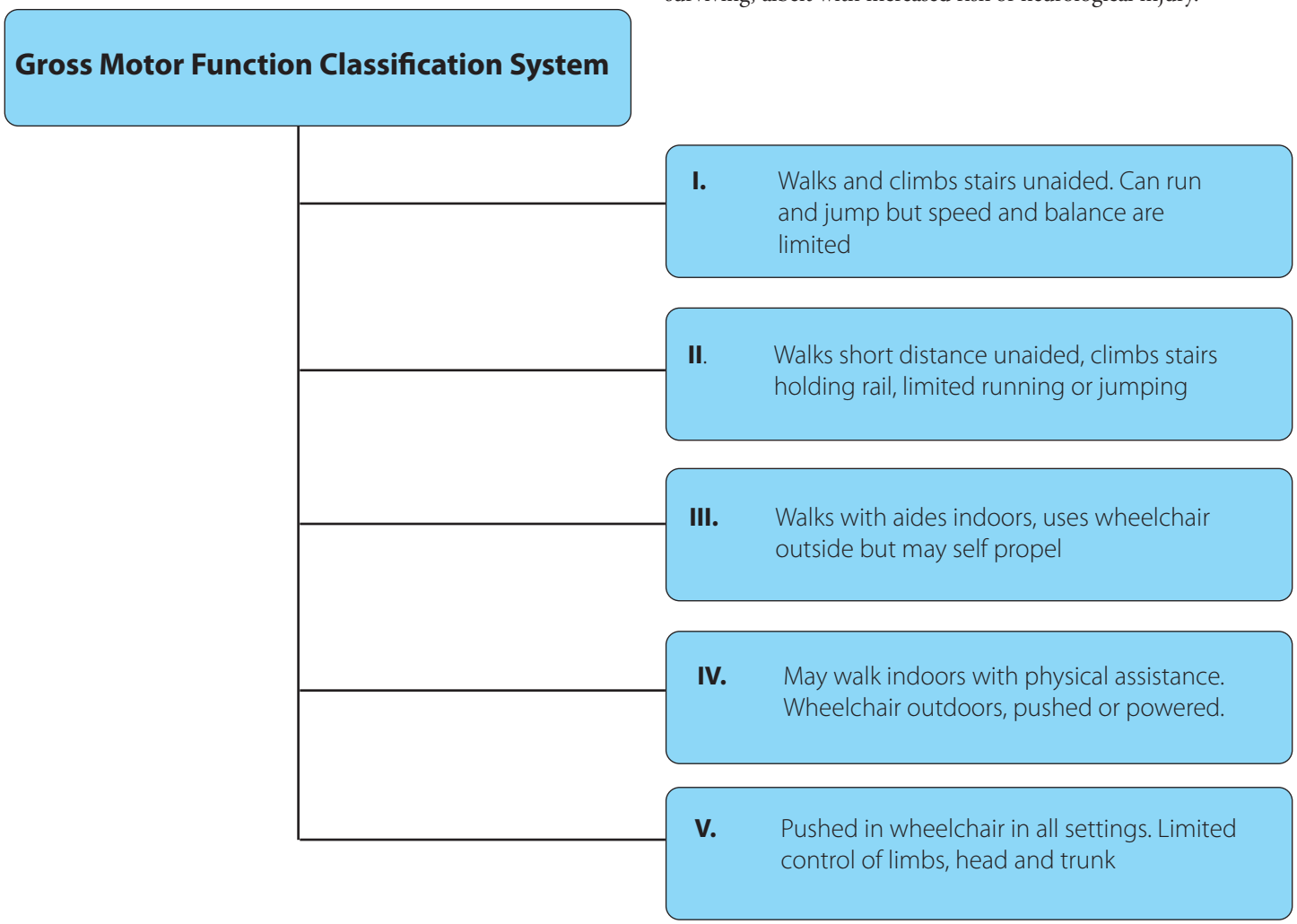
A 15 year old, 45kg male presents to hospital for planned adenotonsillectomy. He suffers from hemiplegic spastic CP. He has difficulty with upper limb fine motor skills however walks unaided. He met all developmental milestones as a child and expects to go to college next year.

Although a thorough history, examination and review of medical notes should still be performed, this adolescent appears to be significantly less medically complex than the child in case study 1. He is presenting for surgery unrelated to his CP and could potentially be considered for day case surgery.

INCIDENCE

Cerebral palsy is the most common childhood motor disability, currently affecting 2.5 per 1000 live births in the UK[1] and up to 4 per 1000 live births in low and middle income countries (LMIC)[2]. Due to the larger populations, it is thought that around 80% of people with CP live in LMIC. In higher income countries where a number of risk factors have reduced in recent decades, such as antenatal infections, the remarkably stable incidence of CP cases has been attributed to the rising number of premature babies that are surviving, albeit with increased risk of neurological injury.

Figure 1: Classification of Cerebral Palsy[1]



AETIOLOGY

The diagnosis of CP is essentially clinical although radiological techniques such as magnetic resonance imaging (MRI) may identify associated features such a periventricular leukomalacia[3]. Around two thirds of cases have an identifiable cause. Although in the remaining third the cause is unclear, there are a number of recognised risk factors listed in Table 2. Whilst it can be difficult to identify when the neurological insult occurred, it is thought that around 80% occur during the antenatal period and the remaining occur after birth and within the first 2 years of life.

PROGNOSIS

Predicting life expectancy in a condition with such heterogeneity needs an individualised approach. A patient that is functionally independent with minimal systemic involvement can expect a life expectancy similar to the general adult population. The same would be unlikely to apply to a quadriplegic, dependent child with chronic lung disease and multiple hospital admissions. Prognosis will also depend upon the availability of resources. In settings where the burden of care is placed on the family unit, those living in poverty and with severe disability may not live into adulthood. Life expectancy continues to increase for such patients in high resource settings.

TREATMENT

Cerebral palsy is best managed using a well coordinated multidisciplinary team (MDT) approach. Rarely will a single treatment in isolation provide sustained functional improvement, rather, this may be achieved by a team of health professionals working with an informed and engaged patient and family. Healthcare provision is increasingly focused on improving quality of life. Reducing spasticity and contractures, and improving and maintaining range of movement aims to increase patient independence. Assessing the effectiveness of interventions in this heterogeneous condition is difficult however and patient management decisions are often made on an individual basis supported by a limited body of evidence[4].

Case study 3

David, a 14 yr old boy living in a LMIC has diplegic spastic CP. He can only mobilise independently by crawling although he can stand with a frame if someone is there to assist him. Due to his poor mobility he has no formal education despite having normal intellect and is unable to help with the running of the family shop.

Unable to pay for regular private support and treatment, his family enquire about 'one-off' treatments that may help. After a thorough gait assessment, examination and risk benefit discussions with the healthcare team it was decided that 'single event multi level surgery' would be the best option. This would involve tendon lengthening followed by application of limb casting and regular physical therapy sessions in the post operative period.

Three months following surgery and intensive physical therapy, David is able to walk indoors with a frame without assistance. He hopes to be able to continue improving his mobility and be able to walk outside with his frame unaccompanied.

MEDICATIONS

Treatment of spasticity can be at the peripheral or central level. Botulinum toxin A is injected into affected muscles where it is taken up into presynaptic terminals and inhibits acetylcholine release, functionally denervating muscle fibres. The effect acts within 2-3cm of the injection site and lasts between 3 - 6 months[5]. Centrally acting agents include baclofen, diazepam, tizanidine and dantrolene. Baclofen, a gamma-aminobutyric acid (GABA) β agonist, exerts its effect at the dorsal horn. It can be administered via multiple different routes however, along with most other antispasmodic medications, a common side effect is sedation. Intrathecal baclofen pumps (ITP) reduce this effect by 'bypassing' the blood brain barrier allowing for greater efficacy and reduced doses than via other routes. These devices are titratable and reversible however their cost and ongoing maintenance limits their use to the high resource setting.

Table 2: Causes and risk factors for cerebral palsy[6]

Antenatal	Perinatal	Postnatal
Foetal • Vascular anomalies • Genetic/metabolic • Trauma **Maternal** • TORCH* syndrome • Hyperthyroid • Alcohol ** toxoplasmosis, rubella, cytomegalovirus, herpes simplex virus*	• Prematurity • Low birth weight • Multiple pregnancy • Asphyxia at birth • Breech delivery • Pre-eclampsia • Peripartum haemorrhage	• Intracranial haemorrhage • Meningitis or encephalitis • Trauma • Asphyxia

COMMON OPERATIONS AND CASE SELECTION

The decision to undertake surgical interventions depends on various factors such as surgical complexity, cost, equipment availability and support services. In LMIC, surgical interventions that are cheap, require few or no implanted materials, can be performed without specialist surgical skills and require minimal follow-up are generally considered to have the best outcomes[4].

Surgical interventions range from simple, inexpensive operations such as tenotomies, to technically challenging operations, such as spinal correction, that are expensive and need resource intensive aftercare (see Table 3).

ANAESTHESIA FOR CP

A systems based approach will be used to discuss the anaesthetic implications of CP. Unlike some conditions where a certain degree of homogeneity can be expected, patients with CP differ significantly from one another and an individualised approach to each child is essential.

A wide range of anaesthetic techniques may be used depending on the type and length of surgery and individual patient characteristics. Regional and neuro-axial techniques as an adjunct to general anaesthesia can reduce intra and post operative opioid requirements and allow early mobilisation and physical therapy.

NEUROLOGICAL / COMMUNICATION

Around half of all patients with CP have a degree of learning difficulty or intellectual impairment and up to a quarter are unable to talk. Communication may pose significant challenges but it must not be assumed that difficulty speaking reflects low intellect when it may relate to physical manifestations such as oro-motor pathology. Assessment of pain can be particularly challenging with subjective indicators like moaning, grimacing and agitated movements being unreliable indicators of distress. Parents or guardians will be invaluable in assisting staff in a wide range of aspects of care throughout the child's 'healthcare journey'.

Ten percent of patients have severe visual impairment and a significant number suffer auditory involvement. Consideration needs to be given to aspects of care reliant on these senses such as the use of visual analogue scores for assessing pain and individualised alternatives arranged.

Volatile and intravenous anaesthetic agents, muscle relaxants, sedatives, opioids and local anaesthetics have all been used safely in CP patients. Minimum alveolar concentration (MAC) appears to be reduced and resistance to muscle relaxants has been noted, possibly due to the presence of extra junctional acetacholine receptors. Of note, succinylcholine use in this cohort is not associated with hyperkalaemia[6].

Epilepsy is a common association affecting around 1 in 4 patients. For some this may be poorly controlled and planning for the hospital admission should take this into account. There are multiple interactions and side effects from anti-epileptic medications that could impact on the perioperative management of these patients and anaesthetists should be familiar with those most commonly prescribed.

Table 3: Reasons for anaesthesia in cerebral palsy patients

Neuro surgery

Dorsal rhizotomy

Ventriculo-peritoneal shunts

Ablation of dorsal root ganglion

Baclofen pump insertion

Opthalmic

Squint correction

ENT

Cochlear implants

Tracheostomy

Orthopaedic surgery

Tendon surgery – transfer, removal, lengthening (often adductor/ psoas/ achilles) Pelvic and femoral osteotomies

Hip spica

Spinal surgery – scoliosis correction

Botulinium toxin A muscle injections

Maxilofacial / dental

Tooth extraction

Salivary gland surgery

General surgery

Gastroscopy / colonoscopy

PEG insertion

Manual evacuation of faeces

Fundoplication

Radiology

Typically central nervous system or musculoskeletal

Key anaesthetic considerations regarding antiepileptic medications:

- *Identify dose, timings, interactions*
- *Ensure drugs are continued and use alternative routes if necessary ie for anticipated poor oral absorption post operatively*
- *A number of anaesthetic agents have been identified as having epileptogenic activity, these include enflurane, methohexital, etomidate and ketamine, although the latter can also have anti seizure properties at higher doses.*
- *Analgesics associated with decreased seizure threshold include alfentanil, tramadol and pethedine*

Key anaesthetic considerations:

- *Establish communication requirements and how to identify pain*
- *Consider anxiolytic premedication but be aware of the increased depressant effects in this population and reduce the dose and monitor them accordingly*
- *Depth of anaesthesia and neuromuscular monitoring if available*
- *Potential for extreme sensitivity to volatile anaesthetics and opioids in those with severe neurological disability*

RESPIRATORY

Lung function needs careful evaluation when considering anaesthetic intervention. Acute and chronic lung disease may be present due to a number of factors:

- Prematurity and prolonged neonatal ventilation
- Recurrent lower respiratory tract infections (poor cough, reduced immunity)
- Restrictive lung disease related to spinal defects ie scoliosis
- Recurrent aspiration (GORD, bulbar involvement)

Key anaesthetic considerations

- *Thorough respiratory system examination*
- *Spirometry and chest X-ray if appropriate or available*
- *Pre-optimisation of lung function (this may include physiotherapy, steroids, bronchodilators, antibiotics, mucolytics)*
- *High dependency care post operatively if available*

GASTROINTESTINAL

A significant proportion of CP sufferers will have a low body mass index (BMI) and be at risk of dehydration, electrolyte imbalance and a variety of longer term consequences of malnutrition such as anaemia and vitamin deficiency. This situation may occur for a variety of reasons such as a limited ability to communicate or independently feed oneself, limited oro-motor control and severe gastro oesophageal reflux disease.

Fat reserves and muscle mass may be reduced and the resulting large surface area to weight ratio can mimic that of a neonate. Clinicians should be vigilant with pre, intra and postoperative temperature regulation. Children are particularly vulnerable following induction of anaesthesia. Prolonged exposure may occur whilst obtaining intravenous access; performing regional anaesthesia; positioning for surgery; or attaching neuromuscular monitoring. This may result in clinically significant drops in core body temperature. Adverse effects from perioperative hypothermia are well documented and include coagulopathies, wound infection and altered drug metabolism. Techniques such as warming before and after surgery have been implemented to good effect and a range of options exist for intra operative warming.

There has been much recent discussion regarding preoperative starvation times in children and recent guidance[7] recommends that unless contraindicated, patients should be allowed clear fluids up to 1 hour before anaesthesia commences for elective surgery. For reasons already discussed, CP patients are particularly prone to dehydration, with evidence suggesting that preoperative haematocrit values may reach as high as 55%[8]. Unresolved dehydration has many unwanted effects including increased risk of renal dysfunction and thromboembolism and clinicians should consider keeping fluid restriction to a minimum and ensuring adequate hydration intraoperatively.

Key anaesthetic considerations

- *Pre-optimisation of gastric reflux (with proton pump inhibitors or histamine receptor antagonists). Consider rapid sequence induction if there is poorly controlled reflux.*
- *Strict temperature control perioperatively. Use of active heating systems such as forced air warmers. Warm IV fluids and blood products before administration. Continuous temperature monitoring may be appropriate.*
- *Antisialogogue for excessive drooling ie glycopyrolate and suction to hand during induction of anaesthesia*
- *Minimise starvation times*
- *Postoperative laxative administration, especially with high dose or prolonged opioid use*
- *Urea and electrolyte studies for larger operations or where gastrointestinal or renal involvement is possible*

MUSCULOSKELETAL AND SKIN

Although the initial lesion in CP occurs within the central nervous system, many of the typical features develop at the muscular level. Over time and without intervention, changes in tone and loss of function result in short, 'stiff' muscles known as contractures. Whilst the aetiology, size and location of the central lesions vary, phenotypically the presenting features are often similar. This is because larger, stronger muscle groups exert their dominance over smaller, weaker ones. As such, contractures typically result in flexion at the hips and knees; plantar flexion at the ankles; and flexion at the elbow[8]. Abnormal core and paraspinal muscle tone causes scoliosis and pelvic obliquity. There appears to be a relationship between GMFCS level and severity of scoliosis with half of all children GMFCS IV-V developing a severe scoliosis. Unlike with idiopathic scoliosis, CP related scoliosis may continue to progress beyond spinal maturity without intervention.

The ability of muscle to contract to reduce blood loss when damaged or incised is diminished in CP and significant blood loss should be anticipated and prepared for when moderate to major surgery is being performed. Assessment of blood loss during surgery can be difficult and small quantities in neonates for example, can be clinically important. Careful monitoring of blood in suction containers, blood on drapes / gauze, oozing from wound edges and discussion with surgeons can all assist anaesthetic staff in appropriate decision making. Trends in clinical observations such as rising heart rate may be indicators of significant blood loss. Thromboelastography (TEG) provides real-time assessment of blood clotting ability in patients and can guide the use of clotting factors and platelets during major bleeding episodes.

Muscle spasm in the post operative period is a common feature of muscluloskeletal surgery in CP. This can be extremely painful and distressing for the child who may have difficulty communicating such problems. Pain from muscle spasm responds poorly to analgesic medicines such as opioids and is best treated with a benzodiazepine and clear guidance to nursing staff of when it should be administered.

Key anaesthetic considerations

- *Anticipate difficult intravenous / intra arterial / central venous access. Use of ultrasound if available*
- *Careful positioning and padding, identifying pressure points unique to the individual.*
- *Thorough postoperative analgesic planning is essential and should focus on a multimodal approach and minimise opioid use if possible.*
- *Prescribe a benzodiazepine for post operative muscle spasm*
- *Continue long term antispasmodic medications or change to alternative route as necessary.*
- *Caudal epidural blocks reduce lower limb muscle spasm in the immediate post operative period*
- *Vigilant haemostasis by surgeons*
- *Perform full blood count and coagulation studies*
- *Consider cell salvage, tranexamic acid and blood product availability*
- *TEG if available*

AIRWAY

A formal airway assessment in this cohort may be challenging. Poor dentition, neck contracture and temporomandibular joint dysfunction may affect airway management and a review of previous anaesthetic notes, if available will assist the anaesthetist in preoperative planning. Obstructive sleep apnoea (OSA) is associated with CP, generally secondary to bulbar involvement or laryngomalacia. Clinicians should review notes and investigation results, such as 'sleep studies' or overnight oxygen saturation levels. Identify whether home continuous positive airway pressure (CPAP) devices are used. If so, it may be appropriate to manage the patient in a high dependency setting post operatively.

Key anaesthetic considerations

- *Review previous anaesthetic notes regarding airway if available*
- *Careful airway assessment (see ATOTW 'The difficult paediatric airway' for further detail)*
- *Have difficult airway equipment available*

CARDIOVASCULAR

Primary cardiac lesions are not associated with CP however cardiovascular insufficiency may develop over time. In those with GMFCS III – V, ability to exercise may be significantly diminished and cardio-respiratory reserve may be poor. Gold standard methods such as cardiopulmonary exercise testing (CPEX) may not be available, or may not be feasible to use in those with limb contractures and or intellectual disability. Taking a focused history, including functional ability over time and performing a cardiovascular examination will guide the clinician but effective methods of determining adults with CP are noted to have higher rates of ischaemic heart disease compared to the general population and clinicians should ensure haemodynamic stability at all times.

Chronic lung disease is associated with raised right heart pressures and may progress to failure with time. Evidence of this on examination may be difficult to elicit and further investigations such as echocardiography and oxygen saturation assessment may be needed preoperatively. Avoidance of hypoxia is especially important in affected individuals.

Key anaesthetic considerations

- *Consider echocardiography (ECHO) and an electrocardiogram (ECG)*
- *Oxygen saturation assessment*

UROLOGY

Urinary incontinence is a common association. The main reasons for this are neurogenic bladder and intellectual impairment, which reduces the ability to learn bladder control. Patients may have indwelling catheters or have undergone repeated intermittent catheterisation. Due to a recurrent exposure to latex catheters, affected children are at higher risk of latex allergy. Catheterisation is also associated with increased rates of urinary tract infection.

SUMMARY

Cerebral palsy is a heterogeneous group of conditions that places a significant global burden on healthcare resources. The treatment options are many and individualised management plans focused on relieving suffering and improving function should be the mainstay of treatment. The anaesthetist must be aware of key aspects of the condition that may be particularly challenging such as communication, pain control and respiratory compromise. Thorough preoperative assessment and planning including discussion with family members will help the team to provide the best healthcare possible.

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Update in
Anaesthesia

Paediatric neuraxial anaesthesia and analgesia

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Abstract

Neuraxial anesthetic techniques are generally safe and effective in children of all ages. Spinal anesthesia may reduce the risk of early post-operative apnea in neonates and former premature infants and is an alternative to general anesthesia in resource-limited settings. Epidural anesthesia may facilitate early tracheal extubation in neonates and is a useful adjunct to multimodal analgesia to spare opioids and enhance recovery in the post-operative period. A large prospective study of >40,000 neuraxial anesthetics demonstrated the safety of epidural catheter placement in children under general anesthesia. Serious complications from pediatric neuraxial anesthesia are rare as demonstrated in case series and the Pediatric Regional Anesthesia Network database.

Key words: analgesia; epidural; anesthesia; spinal; infant; child

INTRODUCTION

Neuraxial anesthesia has been performed safely in pediatric patients for over a century, starting with successful reports of spinal anesthesia by Bier in an 11-year-old child for thigh tumor resection in 1898 and by Bainbridge in a 3-month-old infant for strangulated hernia in 1900[1-2]. Caudal epidural blockade was the next advancement, and by 1954 neuraxial anesthesia had expanded to include a case series of lumbar epidural anesthetics for inguinal hernia repair in infants and children[2]. As the safety of general anesthesia improved, interest in pediatric neuraxial anesthesia waned until a resurgence in the mid 1980s when spinal anesthesia was touted as a safe alternative to general anesthesia to reduce the risk of post-operative apnea for premature infants ≤60 weeks post-menstrual age (PMA).

Spinal Anesthesia

The Vermont Infant Spinal Registry demonstrated spinal anesthesia (SA) in high-risk infants is safe and practical with high anesthetic success rate (95.4%) and low rates of complications of hypoxemia, bradycardia, and postoperative apnea[3]. The 2015 General Anaesthesia Compared to Spinal Anesthesia Consortium (GAS) study compared general anesthesia (GA) to SA and found awake SA to reduce the risk of post-operative apnea within the first 30 minutes in infants ≤60 weeks PMA with no change in incidence of post-operative apnea from 30 minutes to 12 hours[4]. Proponents of neuraxial anesthesia have concerns about the neurotoxicity of GA and its effects on long-term neurodevelopmental outcomes. They advocate for SA as an alternative to minimize or eliminate exposure to potential GA neurotoxicity for procedures less than 90 minutes' duration. While the GAS study demonstrates no impact on 5-year neurodevelopmental outcomes from a single brief <1 hour GA, risks of exposure to longer and/or repeated GA are unknown[5].

Additional benefits of SA over GA in resource-limited settings include reduced need for tracheal intubation in patients with preexisting respiratory difficulties, avoidance of respiratory depressant effects of GA and opioids particularly in premature infants and patients with limited pulmonary reserve, shortened hospital stay, faster OR turnover time, and reduced cost[1].

Epidural Anesthesia and Analgesia (EAA)

While SA can be used as a stand-alone technique, EAA is typically used in combination with intravenous and inhaled anesthetic agents to attain intense anesthetic depth and block the surgical stress response. When an indwelling thoracic or lumbar epidural catheter is placed, EAA can extend analgesia into the postoperative period. There are no large randomized controlled trials in neonates comparing epidural to intravenous postoperative analgesia, but several case series have examined epidural techniques' benefits. In 1998 Bösenberg reported the use of lumbar/thoracic epidural analgesia for major surgery in 237 neonates and ex-premature infants. Due

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to unavailability of infusion equipment, the majority of epidurals were managed postoperatively with intermittent dosing, an effective strategy for resource-limited settings. Bösenberg reported a low rate of complications and advantages including reduced need for post-operative intubation, muscle relaxation, and opioids[6]. A 2009 case series of 40 infants by Shenkman et al. reported benefits of early tracheal extubation in the operating room and good postoperative analgesia using continuous epidural anesthesia for major surgery[7]. Caudal epidural anesthesia/analgesia is the subject of a separate article and is not included in this review.

Advantages:

The advantages of SA or single-injection epidural anesthesia include risk reduction in patients with known or positive family history of malignant hyperthermia and patients with neuromuscular disorders who have restricted cardiopulmonary function. The advantages of EAA with an indwelling catheter are particularly effective for extensive thoracic, intraabdominal-pelvic and lower extremity orthopedic procedures. The postoperative analgesia provided by continuous infusion of a local anesthetic can avoid or minimize use of opioids and related side effects such as nausea, vomiting, ileus, and respiratory depression.

Contraindications:

Neuraxial anesthesia should be absolutely avoided in patients with:

1. Presence of local infection at the needle insertion site
2. Uncorrected hypovolemia or hemodynamic instability
3. Increased intracranial pressure
4. Allergy to the intended local anesthetic
5. And parent or child refusal

Neuraxial anesthesia is relatively contraindicated with patients with:

1. Inherited or acquired coagulation abnormalities due to risk for epidural hematoma (e.g. hemophilia, patient receiving coumadin or heparin, etc.)
2. Presence of systemic infection
3. Anatomic abnormalities such as spina bifida or tethered cord
4. Progressive neurologic disorders
5. And stenotic valvular heart lesions

As with adult patients, epidural catheter placement in adolescents may be performed on awake or lightly sedated patients. In young children and anxious adolescents, epidural catheter placement is commonly performed under GA. A study of >100,000 pediatric regional blockades including almost 40,000 neuraxial blockades demonstrated the safety of neuraxial anesthesia under GA. Neurological and cardiovascular complications were rare with rates similar to those of adult studies[8].

Anatomy and Physiology:

The subarachnoid space is filled with cerebrospinal fluid (CSF) and is present between the arachnoid mater adherent to the deep surface of the dura and the pia mater adherent to the surface of the spinal cord. The conus medullaris terminates at L3 in infants <1 year. Due to differential growth of the spinal cord and vertebrae, the spinal cord will ascend to its adult position of L1-L2 by 1 year of age[9]. Due to the more caudal position of the conus medullaris, spinal anesthesia in infants is performed at the L4-L5 or L5-S1 levels. To determine the level of insertion for SA, palpate the iliac crests to locate the intercristal line (imaginary line drawn between the iliac crests)(Figure 2). The intercristal line, which transects the L4 vertebral body in adults, transects L5 in infants and L5 or S1 in neonates[10-12]. CSF volume also varies by age and necessitates larger spinal doses in infants due to a larger CSF volume of distribution of local anesthetics. CSF volume is approximately 10mL/kg in neonates, 4mL/kg in infants and toddlers, and 2mL/kg in older children and adults[12].

The epidural space is a potential space containing fat, blood vessels, lymphatics, and spinal roots located between the ligamentum flavum lining the bony spinal canal posteriorly and the dura mater anteriorly. The epidural space can be accessed by passing through the ligamentum flavum at thoracic and lumbar levels or the sacrococcygeal ligament of the sacral hiatus in the caudal region (Figure 1). Epidural landmarks include the intercristal line for lumbar epidurals as well as an imaginary line drawn between the inferior scapular borders which transects the T7 or T8 spinous process and serves as a landmark for thoracic epidurals. The distance from skin to epidural space varies by age. Below 6 months, skin to epidural distance is 5-12mm and does not correlate with weight. From 6 months to 10 years, the distance is approximately 1mm/kg[13]. A thinner ligamentum flavum yields a subtler loss of resistance during insertion of epidural needles in young children, although a more compliant epidural space eases insertion of the epidural catheter[2,14].

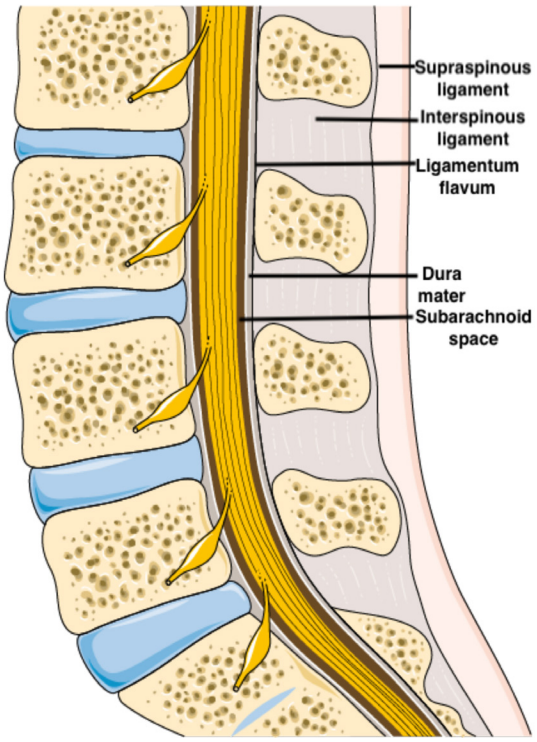

Figure 1: Anatomy of the lumbar epidural space

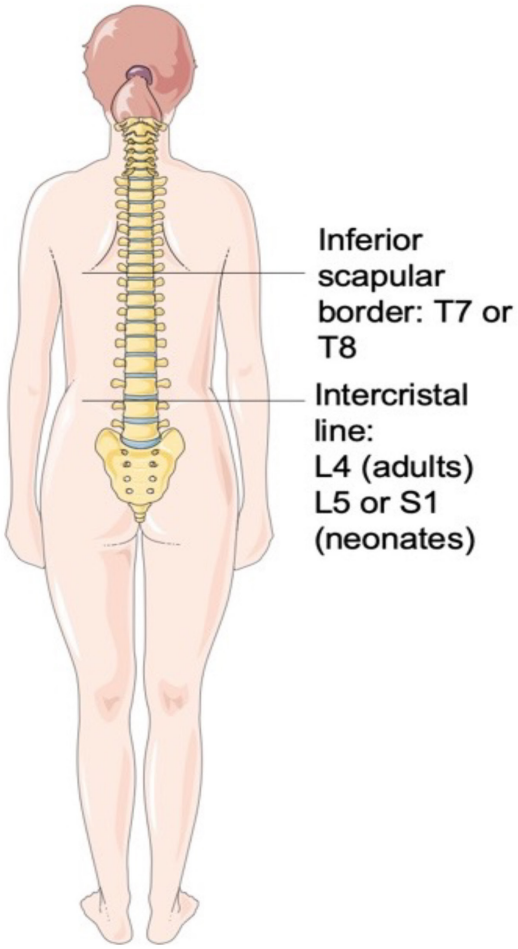

Figure 2: Anatomic landmarks for epidural insertion sites

In older children and adults, neuraxial anesthesia attenuates sympathetic tone leading to vasodilation, hypotension, and bradycardia. Bradycardia is especially likely when anesthetic level rises to high thoracic levels > T2-4 where the cardioaccelerator fibers originate. In infants and some toddlers in whom the parasympathetic nervous system predominates, neuraxial anesthesia is associated with hemodynamic stability. In Bosenberg's case series, 0 of 234 neonates had a change in systolic blood pressure >20% from baseline and 15 of 234 required administration of Atropine for heart rate <100 beats per minute[6]. As in adults, hypotension is treated with a fluid bolus and vasoactive drugs such as intravenous epinephrine.

Management of Patients Receiving Neuraxial Anesthesia:

Pre-procedure consent should be obtained from the guardian and assent from the patient when appropriate. Coagulation studies including platelet count, INR (International Normalized Ratio), and PTT (Partial Thromboplastin Time) should be obtained in patients with risk for coagulopathy such as personal history of spontaneous bleeding or prolonged surgical bleeding, family history of coagulopathy, or cirrhosis. Children with an INR ≤1.4 who are not on warfarin are not at increased risk of spinal bleeding and may safely undergo neuraxial anesthesia or removal of a catheter in accordance with ASRA (American Society of Regional Anesthesia) guidelines[15]. If a patient is on warfarin, it should be discontinued for 5 days and INR is allowed to normalize to <1.2. A consensus threshold for thrombocytopenia has not been established, but expert opinion generally supports the following thresholds: platelet count ≥100,000-150,000/μL (baseline risk of spinal bleeding, neuraxial anesthesia may be safely performed), 75,000-100,000/μL (low bleeding risk if stable platelet count and absence of clinical bleeding), 50,000-75,000/μL (increased bleeding risk, risk may be acceptable if benefit of neuraxial anesthesia outweighs risks and provided that platelet function is normal), and <50,000/μL (high bleeding risk, acceptable only in limited circumstances). Coagulation studies are not indicated for routine neuraxial anesthesia in healthy children. Children receiving anticoagulant medications should follow ASRA or ESA (European Society of Anaesthesiology) guidelines[15-16]. NPO guidelines should be followed as for general anesthesia.

Premedication can be given as indicated. For patients undergoing awake neuraxial procedures, topical anesthesia such as EMLA (Eutectic Mixture of Lidocaine and Prilocaine) 5% cream or tetracaine 4% gel (Ametop or AnGel) should be applied to the anticipated needle puncture site. Consider use of lidocaine 4% cream in premature and term infants under 1 month of age due to risk for methemoglobinemia with use of EMLA 5% cream and tetracaine 4% gel[17]. Obtain intravenous access prior to induction of neuraxial anesthesia to allow the rapid administration of vasoactive agents or intralipid in the event of peri-neuraxial hemodynamic instability or accidental systemic toxicity. Calculate the maximum allowable dose of local anesthetic (Table 1), the anticipated spinal (Table 3) or epidural (Table 4) bolus dose, and the epidural test dose, if indicated. There are no controlled trials to guide dosing in awake infants and children, and all dosing recommendations are based on observational studies. The dosing guide for spinal anesthesia in awake infants or sedated older children is based on targeting a T4 sensory dermatome for indicated surgical procedures below the T10 spinal segment. Epidural dosing is based on multiple studies that retrospectively estimated the dosing regimens by assessing the regression of sensory dermatomes after patients awaken from general anesthesia. Most recommended dosing regimens are estimated on the maximum allowable dose of local anesthetic given to children under general anesthesia (Table 1).

Table 1: Maximum recommended dose of local anesthetics for epidural administration[14]

Local anesthetic	Maximum dose (mg·kg-1)*	Duration (min)
Bupivacaine or levobupivacaine	2.5	80-600
Ropivacaine	3	120-240
2-Chlorprocaine	11 (without epinephrine) 14 (with epinephrine)	30-60
Lidocaine	5 (without epinephrine) 7 (with epinephrine)	90-200

Intra-Procedure

Ensure all supplies are gathered at the bedside and perform a "time-out" checklist prior to beginning the neuraxial blockade. Apply standard ASA monitors. Position the patient in a lateral or seated position, as desired. Ensure the spine is flexed into a C-shape while the head is extended to maintain a patent airway. Some advocate seated or reverse Trendelenburg lateral positioning for neonatal SA to maximize hydrostatic pressure and enhance CSF efflux from small diameter spinal needles[12,14]. An assistant should be available to aid in positioning, patient monitoring, and airway management. Use universal infection precaution for procedural sterility and follow standard practice for skin preparation. Skin antiseptic solution should be allowed adequate drying time for effectiveness, for example chlorohexidine gluconate requires a minimum of 3 minutes.

Spinal anesthesia in infants is typically performed with a 22g (Quincke tip) or 25g (pencil tip) spinal needle. Smaller needles can delay CSF efflux rate but significantly reduce the incidence of post-dural puncture headaches in children. Pencil tip needles are not used in infants due to difficult placement of the side opening into the narrow subarachnoid space and low CSF pressure causing very slow flow of CSF into the needle hub. Blunt tip needles should be used in infants and toddlers when possible and are associated with lower rates of post-dural puncture headaches.

The spinal needle should be inserted with stylet until increased resistance is felt with engagement of ligamentum flavum. A stylet is used to prevent iatrogenic implantation of skin and subcutaneous tissue that may introduce infection or grow over time into spinal epidermoid tumors. The needle is advanced slowly until a "pop" is felt. After stylet removal, free flow of clear CSF indicates correct placement in the subarachnoid space. The weight-based dose of local anesthetic is then slowly injected. (Table 3) 1-mL syringes are preferred for measuring a unit dose of local anesthetic and avoiding errors. The duration of action of spinal anesthesia can be prolonged with the addition of adjunctive agents such as epinephrine, opioids, or clonidine in older children.

Baricity of the local anesthetic injected into subarachnoid space combined with patient positioning will affect the desired anesthetic height attained. Hyperbaric solutions are heavier than CSF and spread in the direction of gravity. A hyperbaric spinal dose in a child who remains seated will spread in a caudate direction resulting in coverage of primarily sacral dermatomes, a "saddle" blockade. If a higher dermatome is desired, the child should be quickly placed supine after a hyperbaric dose is administered to allow more even spread in the cranial-caudate dimension. On the other hand, a hypobaric [lighter than CSF] spinal dose will primarily spread in the opposite direction to gravity in a seated or lateral decubitus child. The spread of isobaric [of equal density to CSF] spinal doses is less affected by patient position/gravity and will concentrate at the site of injection.

Table 2: Appropriate size of epidural Tuohy needle by age[20]

Age (years)	Epidural needle gauge
0-6	20
7-10	19
>10	18 or 19

Epidural Anesthesia (Figure 3) is usually performed at lumbar or thoracic levels where the epidural space can be entered via a midline or paramedian approach. In a midline approach, the epidural needle is introduced between spinous processes and advanced through the supraspinous and interspinous ligaments before piercing ligamentum flavum to enter the epidural space. In the paramedian approach, the epidural needle is inserted lateral to the superior edge of the spinous process. The needle is directed downward at a 90-degree angle to the skin, makes contact with lamina, then is "walked off" the lamina toward the midline into the interlaminal space until it pierces ligamentum flavum and enters the epidural space. The paramedian approach is advantageous for mid to high thoracic epidurals where the spinous processes are angled steeply caudate and a midline approach is more challenging. The paramedian approach should be used cautiously in infants where incomplete ossification of the neuraxial skeleton makes identification of laminae challenging and introduces potential damage to ossification centers[9,14].

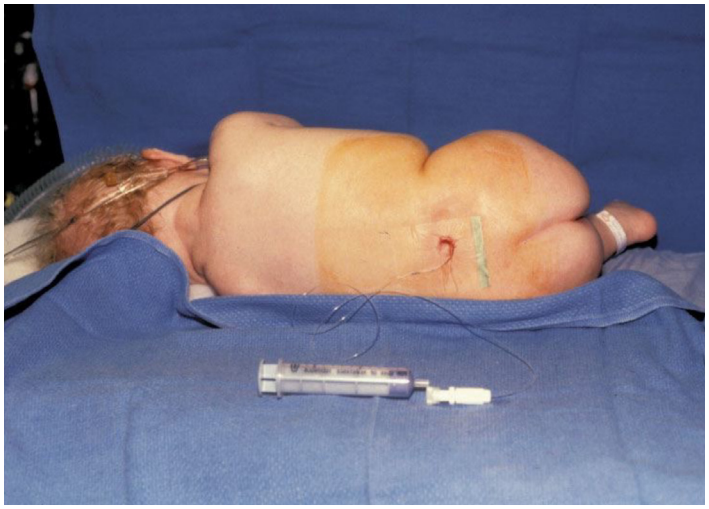

Figure 3: Epidural catheter in a neonate

An appropriately-sized styleted epidural needle such as a Tuohy or Crawford (thoracic spine) is inserted via the midline or paramedian technique until loss of resistance is attained (Table 2). When using a syringe to identify loss of resistance, saline may be preferable to air in infants as inadvertent injection of even small amounts of air into epidural veins could lead to venous air embolism[18]. The epidural catheter is inserted through the epidural needle to the desired surgical dermatome target. The epidural needle is typically inserted with bevel oriented superiorly so that the epidural catheter threads in a cranial direction. Special care should be taken to thread multiple orifice epidural catheters deep enough that all orifices lie within the epidural space. Alternatively, an open-ended epidural catheter can be used. The epidural catheter tip for post-operative analgesia is ideally placed at a vertebral level that corresponds with the surgical dermatomes. Important dermatomal reference levels include T4 (nipple line) for thoracic and upper abdominal procedures, T10 (umbilicus) for lower

Table 3: Recommended dosage of pediatric spinal anesthetics[1,12,21]

Local Anesthetic	Weight (kg)	Dosage	Mean Duration of Anesthesia (min)
Tetracaine 0.5% in 5% dextrose (hyperbaric)	<5	0.5-1mg·kg^{-1} (0.1-0.2 mL·kg-1)	90
	5-15	0.4mg·kg^{-1} (0.08 mL·kg-	
	>15	1 0.3mg·kg^{-1} (0.06mL·kg^{-1})	
Ropivacaine 0.5% (isobaric)	<5 kg	0.5-1 mg·kg-1 (0.1-0.2 mL·kg-1)	96
	≥5 kg	0.5 mg·kg-1 (0.1 mL·kg-1)	
Bupivacaine or levobupivacaine* 0.5% (isobaric or hyperbaric)	<5	0.5-1 mg·kg-1 (0.1-0.2 mL·kg-1)	80
	5-15	0.4 mg·kg-1 (0.08 mL·kg-1)	
	>15	0.3 mg·kg-1 (0.06 mL·kg-1)	

* is used off-label in the USA.

abdominal and pelvic procedures, and L1 (inguinal crease) for lower extremity procedures.

After a negative aspiration of the epidural catheter for blood, most anesthesiologists administer a test dose of 0.5mcg/kg epinephrine, typically accomplished with 0.1mL/kg local anesthetic with 1:200,000 epinephrine. A sudden increase in heart rate ≥10 beats per minute above baseline or increase in systolic blood pressure ≥15 mmHg above baseline within 90 seconds of injection is indicative of intravascular injection. The sensitivity of this test dose is increased by atropine premedication in patients receiving halothane and isoflurane (but not sevoflurane) anesthesia[19].

Of note, aspiration of the epidural catheter for blood may yield a false negative result in children due to low venous pressures and epidural venous collapse during aspiration. Furthermore, the routine administration of test dose in infants and children is controversial because of low sensitivity and specificity under GA. It is therefore recommended to include epinephrine in the epidural loading dose (Table 4). The loading dose should be administered incrementally with intermittent aspiration in 0.1-0.2mL/kg aliquots while observing for changes in heart rate and blood pressure as indicators of systemic toxicity[19]. Preservative-free adjunctive agents including fentanyl, morphine, clonidine, can be added to epidural solutions to augment analgesic properties and requires close monitoring for potential respiratory depression.

A simple estimation of the required volume of local anesthetic needed to block one spinal dermatome in older children follows:

Volume (mL per segment) = age in years / 10

with a maximum volume of 1mL/segment achieved by age 10-12 years.[20]. The total dose of local anesthetic delivered should not exceed recommended dosages as listed in Table 4. Further information about the anatomy and performance of neuraxial anesthesia can be found at **https://www.nysora.com/**.

Complications:

Serious complications from pediatric neuraxial anesthesia are rare, but can occur due to inadvertent intravascular injection of local anesthetic resulting in systemic toxicity such as seizures and cardiovascular collapse. Anesthesiologists providing neuraxial anesthesia should be familiar with guidelines for the management of local anesthetic systemic toxicity including initiation of cardiopulmonary resuscitation, use of lower doses of epinephrine (≤1mcg/kg), and administration of lipid emulsion[22]. A checklist for treatment can be downloaded at **https://www.asra.com/content/documents/asra_last_checklist_2018.pdf**.

Other serious complications include accidental intrathecal injection; high spinal anesthesia leading to hypotension, bradycardia, and even respiratory arrest; epidural hematoma that may compress the spinal

Table 4: Recommended dosage of pediatric epidural continuous infusion[21]

Local Anesthetic	Initial Bolus Dose (mL·kg^{-1})	Subsequent Bolus Dose after 2 hours (mL·kg^{-1})	Continuous Infusion (mL·kg^{-1}·hr)
Bupivacaine or levobupivcaine 0.25%*	0.5 (lumbar) 0.3 (thoracic)	0.25	<3 months: 0.08 3 months-1year: 0.12 ≥1 year: 0.16
Ropivacaine 0.2%*	0.5 (lumbar) 0.3 (thoracic)	0.25	<3 months: 0.1 3 months-1year: 0.15 ≥1 year: 0.2
2-Chlorprocaine 1.5%*	0.5		<3 months: 0.0133 3 months-1year: 0.02 ≥1 year: 0.0333

*Due to immature hepatic metabolism and low plasma levels of alpha-1 acid glycoprotein, amide local anesthetics can accumulate in infants and young children leading to high free plasma levels and toxicity. The ester 2-Chlorprocaine is preferred in this age group because it is metabolized in the plasma by pseudocholinesterase.

cord; epidural abscess; meningitis; needle-induced injury to nerve roots or the spinal cord; venous air embolism; and delayed respiratory depression from opioids. Less serious complications include post-dural puncture headache, transient neurologic symptoms from SA, unilateral or patchy epidural blockade, and cutaneous infection at the site of an indwelling epidural catheter. A Pediatric Regional Anesthesia Network trial examining more than 41,000 single-injection neuraxial blockades and 13,000 neuraxial continuous catheters identified 5 cases of severe local anesthetic toxicity, 18 cases of respiratory depression (all associated with neuraxial catheters, 15 of 18 with opioid-containing epidural solution), one epidural abscess, no epidural hematomas, and no permanent motor deficits[8].

CONCLUSION

Neuraxial anesthesia is generally safe and effective in children of all ages based on case and case-series reports and Pediatric Regional Anesthesia Network safety data. Spinal anesthesia is a safe alternative to GA in neonates and former premature infants at risk for post-operative apnea as well as in resource-limited settings. EAA may facilitate early tracheal extubation in neonates and is a useful adjunct to multimodal analgesia to spare opioids and enhance recovery in the post-operative period. There are no large randomized controlled data on the efficacy of neuraxial techniques compared to other anesthetic/analgesic modalities on alleviating pain, suppressing the neuroendocrine stress response to surgery, and improving post-surgical outcomes.

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Update in
Anaesthesia

Paediatric anaesthesia outside the operating room in children

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Abstract

The increasing number of procedures carried out in children outside the operating room places a greater demand on anaesthesia care providers by expanding the scope of work and the need to maximize the often-inadequate equipment in the remote settings. The practice and approach in Non-Operating Room Anaesthesia differ between centres across the world largely due to the range of procedures and its indications, skill of personnel as well as available medication and equipment. Every practitioner however believes that adequate quality of care and safety of patients must be ensured just like in the main operating room. It is therefore essential to utilize appropriate protocols and guidelines on patient selection, monitoring and management of common complications for successful outcome.

INTRODUCTION

There has been a significant increase in the number of procedures performed in children outside the operating room over recent years[1]. This increased ability to provide anaesthesia care outside the operating room is due to improved diagnostic techniques and skills of proceduralists as well as the availability of newer and safer drugs, better monitoring devices, new techniques and enhanced attention to safety and quality of care[2,3]. Basic equipment for interventional and diagnostic procedures are being provided in some centres where previously none was available, while in many established children's hospitals, the number of children requiring anaesthetic care outside the operating room is almost the same as for procedures in the operating room[4].

Anaesthesia outside the operating room also referred to Anaesthesia in Remote area or Non-Operating room Anaesthesia (NORA) involves provision of care for a wide range of procedures which may require a form of anaesthesia technique from monitored care to deep sedation or general anaesthesia outside the normal work environment of anaesthetic care provider. While the practice and approach in NORA differ between centres across the world largely due to the range of procedures and its indications, the skill of personnel as well as available medication and equipment, every practitioner believes that maximum efficiency and safety of patient must be ensured just like in the main operating room. Paediatric NORA may be required more frequently than in adults as children are unlikely to be calm and cooperative hence the need for deep sedation and general anaesthesia.

Locations for Anaesthesia Outside the Operating Room

Anaesthesia is provided outside the operating room largely because the procedures may require equipment that is not available in the operating room or is not compatible with the OR setting.

An advantage of carrying out procedures in remote areas is that the OR is made available for other major and lengthy procedures.

Locations for NORA may include:

- Radiology suites for CT scan, MRI, Interventional radiology
- Cardiac catheterization laboratory
- Burns unit
- Dental clinic
- Mental Health Unit for modified electroconvulsive therapy
- Endoscopy suites
- Radiotherapy and chemotherapy units.

Anaesthetic Considerations and Challenges

Anaesthesia outside the operating room can be demanding. Possible challenges must be anticipated and prepared for. If adequate preparation is not ensured, critical incidences may occur in a remote location where appropriate help and intervention may not be readily available. Factors related to the patient, staff, procedure and equipment should be considered and optimized to ensure a safe and quality outcome.

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Patient Factors

Attention to detail in patient selection is key to a successful outcome. A detailed medical including signs and symptoms of current illness as well as respiratory and cardiovascular symptoms should be obtained. Previous anaesthesia, surgery, history suggestive of allergy and medications may provide additional and beneficial information. The period from last meal should be noted since the patient in most instances will come from home on the morning of the procedure. Vital signs and weight of patient should be obtained and documented. Airway assessment is mandatory even when endotracheal intubation or use of supraglottic devices is not intended.

Chest auscultation and heart sounds may reveal cardiac or respiratory pathology with no overt symptoms and signs. Risk assessment and patient selection should be meticulous and well guided considering the clinical skills of practitioners and available equipment and support.

Informed consent must be obtained, and fasting guideline ensured. The likelihood of prolonged fasting with its attendant challenges of dehydration, restlessness and haemodynamic disturbance should be anticipated and prevented. Plans should be made to make venous cannulation as bearable as possible.

Staff

Adequate skills in airway management and the ability to intervene when required is a prerequisite for anaesthesia providers delivering NORA. Many considerations and guidelines have been outlined for non-anaesthetists delivering sedation because the mortality rate due to failed resuscitation were found to be greater when care was not directed by anaesthetists. Procedures in remote areas have been associated with increased morbidity and critical incidents largely due to human error, inability to recognise impeding crisis, inability to manage emergencies and the lack of a trained, skilled assistant[5,6].

The importance of a familiar assistant cannot be overemphasized while working in a remote setting. Necessary help must be secured before it is needed. Knowing in advance where to get help in case one needs it is key to success in handling unanticipated crises in NORA. The place of well functioning teams in NORA cannot be over emphasized and ideally, the team should have worked effectively in an operating room environment before undertaking procedures outside the OR. Communication among the team members needs to be succinct with regular simulation of crisis handling to perfect the performance of the team in a real emergency scenario. Work location outside the operating room will not be a good place to start interacting or orienting a new staff. The informed assistant must be able to anticipate plan and communicate effectively. Anaesthesia staff must be trained and have experience with pre anaesthesia assessment of patients, airway management and cardiopulmonary resuscitation and use of anaesthetic and resuscitation drugs. Non-anaesthesia staff are expected to be knowledgeable in cardiopulmonary emergencies, anaesthetic procedures, equipment and post-operative care and resuscitation[6].

Procedure

The attending anaesthesia provider should have good understanding of the procedure. When in doubt communicating with the surgeon or proceduralist involved is crucial to effective pre-anaesthetic preparation. The required information should include but not limited to the following;

- Nature of the procedure and any special requirements that will influence anaesthesia
- Position
- How long the procedure is anticipated to take
- Associated pain
- Possible side effects
- Equipment and devices to be used.

Adequate communication and cooperation of the various specialists is of utmost importance.

The steps involved should be explained and role(s) to be played by individuals must be clearly understood. This should be explained and documented before the procedure.

Equipment

Many of the remote clinical areas where procedures are carried out may not have been designed with anaesthetic requirement in mind. In many instances these areas were converted from other uses out of demand and necessity. Often the basic and required equipment and facilities for anaesthetic care are overlooked. Where such equipment is provided, it may be old, having previously been used in other suites. Appropriate sizes of devices and adjuncts for paediatric age group should be made available. The anaesthetists working in a remote setting will have to check the anaesthesia machine and be familiar with the design and components which may be more basic compared with the one they are accustomed with in the OR. The safety devices on the machine should also be confirmed. Equipment and monitoring standard must meet the main OR requirements and are outlined below[7].

Physical Structure

- Adequate lighting
- Oxygen and backup
- Wall gases
- Suction and evacuation
- Visual access
- Thermostatic control
- Safe electrical outlets

Environment

- Anaesthesia machine
- Oxygen delivery
- Suction catheters
- Size appropriate airway equipment
- Difficult airway trolley
- Crash cart that is well stocked and regularly checked
- Venous access supplies
- Intravenous pumps/ drip stands

- Basic drugs and drugs for resuscitation
- Defibrillator with both paediatric and adult paddles

Monitors

- Pulse oximetry with audible pulse tone and low threshold alarm
- Capnography
- Blood pressure
- Temperature
- EKG

Transport capability

- Oxygen delivery
- Oxygen tanks
- Portable monitors

There might be specific equipment needs for instance for procedures in the MRI suite.

Conduct of Anaesthesia

Anaesthetists and other providers offer care in its various forms for procedures outside the operating room. They consider the co-morbid condition of the child, the planned procedure, available drugs as well as their expertise, experience and comfort in handling the particular procedure before deciding the anaesthetic technique.

Fasting

Duration of fasting required before procedures requiring various forms of anaesthesia has been a subject of many debates in recent years. The standard of care is to allow enough time for gastric emptying. For elective procedure the fasting guidelines of intake of are the same as for normal procedures with solids at 6 hours, breast milk at 4 hours or one missed feed for those feeding more regularly and one to two hours for clear fluids. This is still widely used in many centres. In emergency procedures requiring sedation and anaesthesia the risks and benefits should be weighed and communicated to the parent or guardian. Clear documentation of NPO status and exceptions for example oral medications should be well stated.

Informed Consent

Basic information about the procedure as well as the need for intravenous catheters and use of medications, anaesthetics and analgesics to facilitate patient's cooperation, ensure calmness and prevent pain and discomfort during procedure should be provided to parent or guardian as well as the patient depending on their age. The use of information leaflets or videos at the clinic and during preoperative assessment might be useful. Available options of anaesthesia and associated risks should also be explained. It is essential that informed consent is obtained and documented.

Equipment Check

This should be carried out and clearly documented at the beginning of the day stating the location to be used precisely. Required equipment include although not limited to those listed above. Charts and checklists must be made available at different locations where anaesthesia is provided outside the OR to ensure every mandatory device or adjunct is in place. Routine maintenance and service of equipment and appropriate notifications is mandatory just like for those in the main OR. The support of biomedical staff is essential and will enhance timely intervention in case of equipment failure and prevent avoidable complications.

Induction

The choice of induction agent should be individualized for every patient. Factors to be considered will include patient clinical condition, the duration of the procedure, intensity of pain involved, side effects of the agent and level of calmness needed for the procedure. The latter is especially important in MRI where motion artefact is a major concern. Managing children with special needs especially those with neurologic deficits and major anomalies can be quite challenging. They often have indications for repeat anaesthesia and display increasing anxiety. Such patients may refuse drugs and can become combative. Principles of care include early recognition, parental support, multidisciplinary planning, clear guidelines about perioperative management of uncooperative children and ethical use of restraint has been found to be successful[8]. Various routes of drug administration are being used to induce anaesthesia including intravenous, inhalational, intramuscular and oral. Maintenance is often by inhalational agent or intravenous infusion. A single dose intravenous induction may suffice for brief non-invasive procedures in a few instances.

There are specific guidelines for various procedures outside the operating room, however anaesthetic agents commonly used include the following:

Midazolam

Provides anxiolysis, sedation and amnesia. It is administered mostly for premedication

Dosages: Oral 0.3-1mg.kg^{-1}, Intranasal 0.2mg.kg^{-1}, Rectally 0.3-1mg.kg^{-1}, Intravenously 0.05-0.1mg.kg^{-1}.

Propofol

Widely used for intravenous induction. It has a fast onset and short duration of action providing rapid recovery with less residual effect. Additional benefit is its anti-emetic effect.

Dose: 2-4mg.kg^{-1}.

Ketamine

Intravenous induction agent with analgesic effect at its subanaesthetic dose. A potent bronchodilator useful in asthmatic. It causes tachycardia, hypertension and excessive secretion.

It can be administered intramuscularly in instances like burns dressing changes. Oral ketamine has been used in dental procedures as well.

Dose: Intravenous 1-2mg.kg^{-1}, Intramuscular 2-5mg.kg^{-1}, Oral 5-10mg.kg^{-1} (mixed with sweet beverage, administered about 30 minutes before procedure), Rectal 5-10mg.kg^{-1}.

Ketofol

Combination of ketamine and propofol. Popular for short procedural

sedation and analgesia. It has haemodynamic stability effect and less respiratory depression. It has been used as an infusion for diagnostic and interventional cardiac catheterization procedures. The optimal combination of ketamine and propofol has been much investigated.

Fentanyl

Potent analgesia often used with other anaesthetic. Can cause hypotension, respiratory depression, apnoea, muscle rigidity, postanaesthetic nausea and vomiting.

Dose: 0.5-2μg.kg^{-1}.

Dexmedetomidine

A newer drug becoming popular for sedation because it does not cause respiratory depression and has haemodynamic stability. It is not readily available in many of the low resource setting but when available the dose is 0.1-1μg.kg^{-1} as a slow infusion or bolus. It is usually given with glycopyrrolate as it tends to cause bradycardia

Regional Anaesthesia Technique

Regional anaesthesia is a safe and effective method of pain control often used as an adjunct general anaesthesia. Its use in non-operating room setting among children include provision of analgesia in the emergency room before surgery, relieve of intractable and chronic pain and insertion of percutaneous peripherally inserted central line[9]. With an experienced anaesthetist, availability of equipment for ultrasound guided block and a well-organized monitoring protocol, more children will benefit from regional technique outside the operating room.

Monitoring

Monitoring devices must be appropriate for the environment with appropriate sizes of probes and blood pressure cuffs readily available. Basic monitoring for anaesthesia outside the operating room is same as appropriate for the main OR. The ASA standards for Basic Anaesthetic Monitoring include the following.

- Pulse oximetry with audible pulse tone and low threshold alarm
- Adequate illumination and exposure of the patient to assess colour
- Anaesthesia machine with O_2 analyser
- Continuous end tidal carbon dioxide analyser with audible alarm
- Continuous ECG
- Temperature monitor

The personnel in charge should closely observe the child's face and chest wall movement and continuously assess the level of sedation and physiologic changes. They should be vigilant for signs of respiratory depression and airway obstruction. Documentation of vital signs throughout the procedure is important. Where electronic recording is not available this should be completed in the chart and kept with patients records. Every handwritten note must be meticulous and clear, ensuring that the characters, digits and symbols used are consistent.

Recovery and Discharge

Many locations where procedures are carried out outside the OR lack a designated area for recovery. Where such facilities exist the appropriate equipment and trained staff may not be available. Depending on the settings anaesthesia care provider may have to observe and monitor the patients in the suite until satisfactorily recovered. Close vigilance to discover any signs of airway obstruction, respiratory depression or haemodynamic disturbances is prudent.

Recovery and discharge protocols are same with other procedures in the OR. Important factors to be considered before discharge include the following[4].

- Patient has pre-procedural mental status restored and can be aroused easily
- Stable cardiorespiratory status, intact protective reflexes and patent airway
- Intact motor function
- A responsible adult must accompany the patient
- Written instructions and emergency number

Complications

Providing anaesthesia in a remote setting may be associated with higher risk compared with procedures inside the OR due to a lot of factors which include:

- Lack of vigilance
- No back up plans
- Inadequate pre-procedural evaluation
- Multiple medications
- Inappropriate choice of anaesthetic technique
- Use of non-anaesthesia staff in complex medical cases
- Poor monitoring

Most reported anaesthesia related complications result from respiration depression or airway obstruction. Cardiac events are often limited to bradycardia secondary to hypoxia.

Hypothermia, aspiration and post-operative nausea and vomiting are also potential challenges which when anticipated can be prevented with adequate preparation and proactive care. Other complications are procedure related and specific for the various diagnostic or interventional operations and techniques used.

Conclusion

There is an increasing request and need to provide anaesthesia for children undergoing procedures outside the familiar operating room environment. It is therefore important to establish system and protocol to enhance safety and quality of care. Guidelines on patient selection, improved monitoring and management of common complications is essential to minimise the potential adverse outcomes. The place of good communications among care providers involved in procedures outside the operating theatre and robust commitment and support of the institution is required for a safe and successful outcome.

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Update in
Anaesthesia

Case Report

Barium bronchogram following hydrostatic reduction of intussusception: presentation of a rare complication and brief review of literature

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Abstract

Intussusception is one of the most common paediatric emergencies. Frequently occurs in males under the age of two years. Majority of cases are idiopathic. The accepted initial treatment of uncomplicated intussusception is non-surgical enema reduction using pneumatic or hydrostatic techniques (HR) under fluoroscopic or ultrasound guidance. For HR Barium (Ba) or saline can be used. Complications of HR are rare even though failure to reduce and perforation has been reported. Barium aspiration following HR is hitherto unreported. Ba aspiration in adults and children has been reported following various upper GI contrast studies[1]. We report a case of Ba aspiration following HR of intussusception in a 9 month old child under general anaesthesia. Ba as such is inert, but can remain in lungs for longer period of time and can confuse future imaging studies of respiratory tract.

Key words: intussusception; hydrostatic reduction; barium aspiration; barium bronchogram.

INTRODUCTION

Intussusception refers to the invagination of a part of the intestine into itself. In uncomplicated cases the accepted initial treatment of intussusception is non-surgical enema reduction using pneumatic or hydrostatic techniques under fluoroscopic or USG guidance with or without anaesthesia. For HR barium or saline can be used. Even though ultrasound-guided saline reduction is currently favoured[2] in our institution we still use Ba for HR under fluoroscopy. Complications are rare with HR but rarely failure to reduce. or perforation has been reporte[3]. Xie Xiaolong, in a recent study retrospectively reported 637 patients with intussusception[4]. A total of 621 episodes of intussusception were collected for final analysis out of which 62 (9.98%) patients suffered failed reduction. We present a hitherto unreported complication in an infant following HR, and review the literature briefly.

Case presentation

Intussusception is one of the most common paediatric emergencies. We report a rare complication of hydrostatic reduction under general anaesthesia and review the limited available literature. A 9 month otherwise healthy child weighing 10kg presented with classical signs of intussusception. He was posted for hydrostatic reduction under fluoroscopy/Ga. The baby presented with a history of vomiting, incessant crying and failure to feed. Constipated for one day, pre-rectal examination revealed blood stained gloved finger. Hydrostatic reduction was attempted using Ba after induction of Ga. As per our anaesthetic protocol, we gave IV Ketamine 2mg.kg anaesthesia was maintained holding mask with sevoflurane in oxygen and nitrous oxide mixture. Reduction was achieved within 10 minutes. Throughout the procedure, the child remained hemodynamically stable with SaO_2 100%. Sevofluare and N_2O were stopped and maintained on 100% O_2 while holding the face mask. Suddenly it became increasingly difficult to ventilate with mask and child started to desaturate, simultaneously white coloured thick secretions were noticed while attempting to insert an airway. Immediate oral suction was done. Intubated and kept on 100% Oxygen. Auscultation revealed bilateral crepitations and wheezes. Baby was put on steroids and inhaled bronchodilators. Postoperative chest X-ray showed extensive opacities suggestive of Ba aspiration. Several attempts were made to suck out Ba through the endotracheal tube but little could be retrieved. A feeding tube was passed to empty the stomach. Bronchoscopy or BAL was not performed. He was shifted to Paediatric ICU for further management. Extubated after 48 hrs un-eventfully. Remained stable after extubation. Baby was discharged on 5th day.

Post aspiration

X-ray showed well-defined radio-opaque opacities

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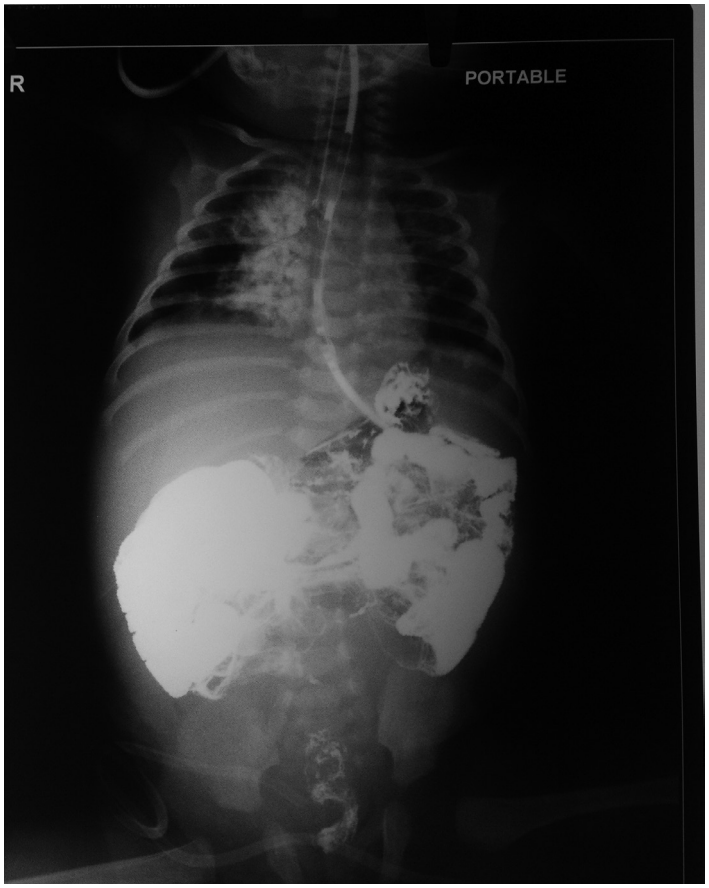

Figure 1: Barium in lungs X-ray

through all zones of the right lung and but less extensive changes on the left side. Also residual Ba in bowel loops was clearly seen. Feeding tube partially filled with Ba also visible. Ba had accumulated mainly in the Rt lung may be due to the supine position.

Discussion

In our institution over a period of 10 years we have performed approximately 240 cases of HR using Ba. This was the only case of Ba aspiration following HR during this period. Intussusception typically presents with the sudden onset of colicky but worsening abdominal pain, sometimes with vomiting and bloody stools, alternating with relatively pain-free periods. If left untreated, the bowel can perforate.

Management choices

For stable patients with evidence of intussusception non-operative reduction is recommended (HR). This procedure involves introducing a substance (air or liquid) into the bowel, via the rectum, with a set pressure that reduces the 'telescoped' bowel into its normal position. The standard method of reduction is to place a reservoir of contrast 100cm above the patient to ensure sustained and constant hydrostatic pressure. Ba (50% dilution of 125w/v Ba.) is used as the contrast agent. Successful reduction is indicated by the free flow of contrast into the small intestine. Very few complications are associated with HR with or without GA. Perforation and failure of reduction has been reported[3,4] Ba regurgitation and aspiration following HR has never been reported in literature.

In our case the standard protocol for Ba reduction was followed regarding the height of Ba container. Here Ba enema successfully reduced the intussusception and may be through an incompetent ilieocecal valve entered the large intestine from there to the small intestine and filled the stomach leading to regurgitation and aspiration. We did not anticipate this event and were caught unaware. Several cases of Ba aspiration has been described following upper GI contrast studies. Most of them are usually associated with congenital malformations of gut and airway, like tracheo-oesophageal cleft, tracheo-oesophageal fistula.[5] Ba is inert as such but since it went through the stomach chances of chemical broncho pneumonia was there. In modern era Ba aspiration is typically accidental.[7] Aspiration of significant amounts of Ba in infants is rare and there is no consensus in the literature on how to manage such aspiration. The sequalae of Ba aspiration depends largely on various factors including patient's age, pre-existing lung conditions, the strength of the Ba used[6,7], the volume aspirated, and the presence of gastric contents[10] the subject's posture at the time of aspiration and respiratory clearance mechanisms such as cough can affect the eventual presence of Ba in the tracheobronchial tree and lungs. Few reports are there in infants. Acute respiratory distress, pneumonitis, sepsis, and even death has been reported in adults[6]. Aspiration of Ba along with gastric contents can give a conflicting picture. Lopez-Castilla et al. reports ARDS like picture and the resultant desaturation in a 2-month-old child with gastro-oesophageal reflux after aspirating Ba following a contrast study[1]. In an attempt to clear the Ba, fibreoptic bronchoalveolar lavages (BAL) were tried. A CT scan of the chest taken 4 months later still showed Ba and micro-nodular densities.

BAL is not routinely recommended as suggested by Wani and Yeola[10], because of the possibility of further spread of Ba down the lungs. Long-term effects of Ba aspiration provide varying information. Small amounts of Ba are well-tolerated. Residual particles that are not expectorated or removed by mucociliary clearance accumulate in alveolar spaces, using high-resolution CT scans Voloudaki et al, inferred that the Ba particles are likely to be phagocytosed by alveolar macrophages and can potentially cause interstitial fibrosis by crossing into the alveolar or peribronchial interstitial tissue[11] Marchiori et al. differs in this matter in their description of Baritosis in which inhaled particulate matter lies in the lungs for years without producing symptoms or significant respiratory impairment[12]. A study in dogs by Wilson et al. only a mild transient inflammatory reaction following Ba brocnhography, which was quickly replaced by a harmless foreign body reaction[13]. The same investigators did not find any ill-effects, either acute or chronic. They concluded that Ba sulfate in the lung behaves as a relatively inert foreign body. Various studies by different investigators involving Ba bronchography has not resulted in short or long term ill effects[14]. The innocent nature of Ba in lungs is provided by Doig who described nine cases of Baritosis in factory workers exposed to Ba dust[15]. He described it as a benign pneumoconiosis. He followed up these subjects for 9 years and reported partial clearing of radiographic changes.

Before the advent of computed tomography and bronchoscopy Ba had been used as a contrast medium for bronchography. Although historically found to be safe in this context, aspiration of Ba may also produce a chemical pneumonitis in some cases.

Limited data exist characterizing the long-term prognoses of patients after isolated Ba aspiration events. Most patients appear to have complete recovery given the inert nature of Ba; however, high-resolution chest imaging has detected subtle evidence of early fibrosis even 1 year after aspiration[11], Wani and Yeola took the contrary view and recommended against bronchoalveolar lavage arguing that it may disseminate the Ba further within the bronchoalveolar system[10].

In paediatrics, imaging techniques may not differentiate primary from secondary aspiration. Factors that are likely to influence outcomes post-aspiration are the child's pre-existing clinical state, the volume, and concentration of the Ba sulfate used as well as the immediate post-aspiration clinical status. If Ba is aspirated, immediate management of Ba aspiration involves an attempt to suck out Ba as much as possible from the tracheobronchial tree and supportive care. Antibiotics and steroids are not indicated routinely Ba aspiration is rare and often produces dramatic radiographic findings, but is generally associated with a favourable prognosis. Evidence favours supportive care in most cases, with therapeutic bronchoalveolar lavage to be considered only in cases with significant respiratory symptomatology[5]. The evidence suggests that the Ba will remain in the lung for an extended time, be relatively inert and that the risk of fibrosis or other complications remains low.

Conclusion

Ba aspiration has been reported following several Ba studies. Since Ba can remain in lungs for an indefinite period of time and can interfere with future radiological studies parents were warned about this. Literature review did not reveal Ba aspiration following hydrostatic reduction of intussusception in a child. In the above case after iv induction, anaesthesia was maintained holding mask. We still continue the same technique. However, endotracheal intubaton and protection of airway should be seriously considered we hereby report this rare complication and alert the concerned physicians about this potentially fatal complication.

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Update in Anaesthesia

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