Update in
Anaesthesia

Education for anaesthetists worldwide

- WHO Surgical Safety Checklist
- Pentazocine
- Malignant hyperthermia
- Anaesthesia for paediatric ENT surgery
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The Journal of the World Federation of Societies of Anaesthesiologists

Update in Anaesthesia

Editor's Notes

Update in Anaesthesia - a new chapter

The role of the Publications committee of the WFSA is to promote the production and distribution of good quality educational materials to anaesthetists who are working with poor supplies of up to date books and journals. *Update in Anaesthesia* is the official educational journal of the WFSA and this edition features some important changes to the journal, aiming to deliver the WFSA vision for anaesthesia in a more effective way.

In order to develop the way *Update* is produced we have formed an editorial board made up of the members of the Publications committee who are listed below. We are committed to producing a first class peer-reviewed journal, with a mixture of clinical review articles, original contributions, case reports and self assessment sections. In addition we will describe abstracts of recently published papers of importance in the international literature.

We know that anaesthesia in some developing countries is extremely challenging[1] and associated with an extremely high mortality – as high as 1 in 130 from anaesthesia alone.[2] Research and outcome studies from these parts of the world are rarely published, and the role of the WFSA's Scientific and Research committee is to encourage anaesthesia providers to take an active role in quantifying the level of safety in anaesthesia and evaluating other developments in anaesthesia. The editors of *Update* will now be keen to receive good quality submissions of original scientific research alongside its more traditional clinical review articles. We hope that this will encourage researchers to be active and also to try to improve standards in our specialty by demonstrating good practice and improving outcome data. Submissions should follow the guidelines at the back of this edition. In this issue we include an audit of waiting times for surgery in Zambia, a survey describing the current state of anaesthesia training in French-speaking West Africa and a case report describing a blood salvage technique for use during a ruptured ectopic pregnancy.

Update will continue to print high quality clinical overview articles, focusing on techniques for provision of anaesthesia that are relevant to anaesthetists throughout the world, whether working where resources are freely available or scarce. As far as possible we will respond to requests from readers – the article on pentazocine has been commissioned and written directly in response to such a request.

Update will continue to be published twice a year in English, producing editions in June and December of each year. The June version will be in the format of this edition, the second annual issue will be a 'themed' edition, starting with Basic Science in December 2008. The themed editions will be larger at over 100 pages and feature reprints of older (but re-edited and modernised) *Update* articles, along with newly commissioned articles to cover topics that have not been dealt with before. I am grateful to Matthew Mackenzie for his help in editing the forthcoming Basic Science edition.

We intend to continue translation of the journal into Russian, Chinese, French and Spanish, and plans are in place to produce a Portuguese version from this edition onwards. Details of the editors for each of these editions are available on the back cover of this edition and volunteers with the expertise to assist in translation will be greatly welcomed. We are dependent on the generosity of the WFSA Publications committee budget to fund our work and on the unpaid volunteers who give up their time to help produce the journal. If further sponsorship becomes available, we will increase the numbers of editions produced each year and look to expand the number of languages into which the journal is translated. Every edition is available to be viewed or downloaded free of charge on the WFSA website (www.anaesthesiologists.com) and also on the website of the World Anaesthesia Society (www.worldanaesthesia.org), which has helped the WFSA with projects of this type for many years.

We hope that you will enjoy the journal in its new format, and that you accept the challenge of continuing to strive to develop the standards of anaesthesia internationally. This will improve outcomes for our patients and consequently the standing of our profession.

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The WHO Surgical Safety Checklist

Errors in the operating theatre cost lives; a patient is given adrenaline instead of atropine and suffers a fatal cardiac arrest; severe haemorrhage complicates a hysterectomy – no blood has been ordered; the surgeon and anaesthetist leave a pack in the airway of a child – no checks were made, the child dies. Similar events have occurred in hospitals in every country in the world.

Around 230 million people undergo surgery every year. Of these, 10 million are for pregnancy related conditions and 60 million follow trauma.[1] Conditions for surgical and anaesthetic perioperative care vary greatly throughout the world, and mortality rates following surgery range between 0.4% and 10% in different settings. Direct deaths due to anaesthesia alone vary from around 1:185,000 in countries with well developed training systems and optimum facilities, but they may be as high as 1:150 in parts of the world where it has not been possible to achieve these standards.[2,3] Major morbidity following surgery occurs in 3 – 25% of patients being treated in a hospital setting, and results in unnecessary suffering, expense and possibly long term disability. It is recognised that many deaths and injuries are avoidable.

Many episodes that harm patients are caused by identifiable problems such as poor communication, drug errors and technical issues. The majority of these lapses in care are not intentional or due to carelessness, but result from human error. These problems will always occur, and we need to have robust systems in place to protect our patients.

How can we make surgery and anaesthesia safer? Good communication and theatre teamwork are vital. Checklists, protocols and other aide memoires can reduce the incidence of errors significantly, and at the same time improve the communication and team working between colleagues.[4,5,6] Teams that work well together and focus on the patient have better outcomes. Unfortunately, in many places hierarchies have been created and maintained that allow little opportunity for different professions to feel comfortable working with each other. Juniors are not often invited to challenge seniors; non-physicians find it difficult to question physicians, even if things are going wrong.

The WHO, through its initiative Safe Surgery Saves Lives, has developed guidelines for safe surgery that were launched in Washington on 25th June 2008. As a part of this initiative, the WHO has produced a Surgical Safety Checklist, reproduced in this issue of *Update*, along with the instruction manual for its use. Further information can be found on the WHO website, www.who.int, including the supporting evidence for the recommendations. The Checklist addresses key points in the patient's journey through theatre and is the result of a collaboration of more than 200 agencies, professional organisations and ministries of health involved in surgical care around the world. The WHO also recognises that there is very little published about outcomes from surgery in the developing world, and encourages hospitals to collect this data.

The Checklist is simple in its concept and describes checks in the perioperative pathway at three stages, prior to anaesthesia – the **Sign In**, prior to skin incision – the **Time Out**, and following surgery before leaving theatre – the **Sign Out**.

During **Sign In** the team checks that they have the correct patient, the consent is correct and the surgical site is marked. An anaesthesia safety check is performed to confirm details about the patient such as starvation and airway assessment, and that appropriate drugs and equipment are available and functioning for the anaesthesia required. In particular, a pulse oximeter is highly recommended for every anaesthetic and should be applied before induction of anaesthesia. This simple technology has the potential to save many lives.

The **Time Out** phase ensures the theatre team know each other by name and role, checks that all equipment is available and confirms the correct patient for the correct surgery. At this point both surgeon and anaesthetist describe any particular concerns about the patient or the proposed intervention. Any relevant imaging is checked, also whether antibiotics are required and have been administered.

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During **Sign Out** the final swab count, instruments and samples are checked, along with a discussion about the postoperative plan for the patient. The WHO believes, as do many healthcare organisations around the world, that use of the Checklist will improve surgical safety and encourage a systematic approach to perioperative care. During development many experts considered factors most crucial to patient safety and these have been included. Introducing change into the workplace is not always straightforward and it is advised that the checklist should be adapted to local circumstances. However, just a few minutes to use the Checklist for each patient will make a difference.

Anaesthetists from more than 100 countries read *Update in Anaesthesia*, many of whom work in the most difficult of circumstances, but the Checklist still has much to offer. The Checklist encourages a culture of team working and will challenge hospital managers to support anaesthesia, particularly in the provision of pulse oximetry.

In 2010, the football stars that play best as a team will win the World Cup in South Africa. Technical skills combined with effective communication, mutual respect and organisation will be key. Perhaps the greatest success of the WHO initiative will be if surgeons, anaesthetists and nurses can adopt the same approach, with safe surgery for each and every of one of our patients as our goal.

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News from the WFSA

A big 'thank you' to the editor of *Update*, for offering space to write about the WFSA. First of all I would like to congratulate the editorial team on the new look of *Update* and wish them well in their quest for indexing. This will be a very important step forward in the life of *Update* as a journal. Besides producing *Update*, the Publications committee has developed *Anaesthesia Tutorial of the Week* that is accessed via the World Anaesthesia Society website (www.worldanaesthesia.org) and will soon be available on the WFSA website (www.anaesthesiologists.org).

It is hard to condense the activities and role of the WFSA into a few lines so I will just touch on some highlights of our work. The WFSA is a society of societies, so if you are a member of your national anaesthesia organization, then you are automatically a member of the WFSA. There are now 122 member societies. Ethiopia, Georgia, Laos, Libya and Rwanda were admitted at the World Congress in Cape Town in March 2008.

The objectives of the WFSA are to make available the highest standards of anaesthesia, pain treatment, trauma management and resuscitation to all peoples of the world. These goals are achieved through the work of the WFSA standing committees – Education, Publications, Safety and Quality – all of whose reports are available on the website. The education committee supports training of young anaesthesiologists in WFSA programmes in Chile, Colombia, India, Israel, Romania, Thailand, Tunisia and South Africa. Rotations are available in cardiac, general, obstetric and paediatric anaesthesia, in intensive care and in pain management. In addition, teachers are available for regional and national congresses and workshops.

The Safety committee has produced guidelines to the practice of anaesthesia. It is recognized that, for some, these will be challenging goals to achieve. The Global Oximetry Project is well underway and we hope to be able to expand this with support from the World Health Organization (WHO). Trials of pulse oximeters are ongoing in India, the Philippines, Uganda and Vietnam. Besides introducing the oximeter, all the appropriate education is provided to ensure that the end users are comfortable with the equipment and knowledgeable about the implications of its findings.

Anaesthesia has been an important participant with the WHO in the launch of its Safer Surgery Saves Lives initiative. It is recognized that without safe anaesthesia there will be no safe surgery. The WFSA will be working closely with the WHO to improve anaesthesia safety everywhere.

Over the course of the next four years, the WFSA will take the opportunity provided by this forum to highlight some of our activities in detail. For further information, please look through our website and feel free to contact us at wfsahq@anaesthesiologists.org.

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Update in Anaesthesia

WORLD ALLIANCE FOR PATIENT SAFETY
Safe Surgery Saves Lives

WHO Surgical Safety Checklist (First Edition)
Implementation manual

INTRODUCTION

The **Safe Surgery Saves Lives** initiative was established by the World Alliance for Patient Safety as part of the World Health Organization's efforts to reduce the number of surgical deaths across the world. The aim of this initiative is to harness political commitment and clinical will to address important safety issues, including inadequate anaesthetic safety practices, avoidable surgical infection and poor communication among team members. These have proved to be common, deadly and preventable problems in all countries and settings.

To assist operating teams in reducing the number of these events, the Alliance — in consultation with surgeons, anaesthesiologists, nurses, patient safety experts and patients around the world — has identified a set of safety checks that could be performed in any operating room. The aim of the resulting WHO Surgical Safety Checklist First Edition (available at www.who.int/patientsafety/challenge/safe.surgery/en/index.html) is to reinforce accepted safety practices and foster better communication and teamwork between clinical disciplines. The Checklist is not a regulatory device or a component of official policy; it is intended as a tool for use by clinicians interested in improving the safety of their operations and reducing unnecessary surgical deaths and complications.

HOW TO USE THIS MANUAL

In this manual, the "operating team" is understood to comprise the surgeons, anaesthesia professionals, nurses, technicians and other operating room personnel involved in surgery. Much as an airplane pilot must rely on the ground crew, flight personnel and air traffic controllers for a safe and successful flight, a surgeon is an essential but not solitary member of a team responsible for patient care. The operating team referred to in this manual is therefore composed of all persons involved, each of whom plays a role in ensuring the safety and success of an operation.

This manual provides suggestions for implementing the Checklist, understanding that different practice settings will adapt it to their own circumstances. Each safety check has been included based on clinical evidence or expert opinion that its inclusion will reduce the likelihood of serious, avoidable surgical harm and that adherence to it is unlikely to introduce injury or unmanageable cost. The Checklist was also designed for simplicity and brevity. Many of the individual steps are already accepted as routine practice in facilities around the world, though they are rarely followed in their entirety. Each surgical department must practise with the Checklist and examine how to sensibly integrate these essential safety steps into its normal operative workflow.

The ultimate goal of the WHO Surgical Safety Checklist — and of this manual — is to help ensure that teams consistently follow a few critical safety steps and thereby minimize the most common and avoidable risks endangering the lives and well-being of surgical patients.

HOW TO RUN THE CHECKLIST – IN BRIEF

> *"The Checklist divides the operation into three phases, each corresponding to a specific time period in the normal flow of a procedure."*

In order to implement the Checklist during surgery, a single person must be made responsible for checking the boxes on the list. This designated Checklist coordinator will often be a circulating nurse, but it can be any clinician or healthcare professional participating in the operation.

Figure 1. *The Checklist*

World Health Organization — SURGICAL SAFETY CHECKLIST (FIRST EDITION)

Before induction of anaesthesia ▶▶▶▶▶▶ Before skin incision ▶▶▶▶▶▶▶▶▶▶ Before patient leaves operating room

SIGN IN

- ☐ PATIENT HAS CONFIRMED
  - IDENTITY
  - SITE
  - PROCEDURE
  - CONSENT

- ☐ SITE MARKED/NOT APPLICABLE

- ☐ ANAESTHESIA SAFETY CHECK COMPLETED

- ☐ PULSE OXIMETER ON PATIENT AND FUNCTIONING

DOES PATIENT HAVE A:

KNOWN ALLERGY?
- ☐ NO
- ☐ YES

DIFFICULT AIRWAY/ASPIRATION RISK?
- ☐ NO
- ☐ YES, AND EQUIPMENT/ASSISTANCE AVAILABLE

RISK OF >500ML BLOOD LOSS (7ML/KG IN CHILDREN)?
- ☐ NO
- ☐ YES, AND ADEQUATE INTRAVENOUS ACCESS AND FLUIDS PLANNED

TIME OUT

- ☐ CONFIRM ALL TEAM MEMBERS HAVE INTRODUCED THEMSELVES BY NAME AND ROLE

- ☐ SURGEON, ANAESTHESIA PROFESSIONAL AND NURSE VERBALLY CONFIRM
  - PATIENT
  - SITE
  - PROCEDURE

ANTICIPATED CRITICAL EVENTS

- ☐ SURGEON REVIEWS: WHAT ARE THE CRITICAL OR UNEXPECTED STEPS, OPERATIVE DURATION, ANTICIPATED BLOOD LOSS?

- ☐ ANAESTHESIA TEAM REVIEWS: ARE THERE ANY PATIENT-SPECIFIC CONCERNS?

- ☐ NURSING TEAM REVIEWS: HAS STERILITY (INCLUDING INDICATOR RESULTS) BEEN CONFIRMED? ARE THERE EQUIPMENT ISSUES OR ANY CONCERNS?

HAS ANTIBIOTIC PROPHYLAXIS BEEN GIVEN WITHIN THE LAST 60 MINUTES?
- ☐ YES
- ☐ NOT APPLICABLE

IS ESSENTIAL IMAGING DISPLAYED?
- ☐ YES
- ☐ NOT APPLICABLE

SIGN OUT

- ☐ NURSE VERBALLY CONFIRMS WITH THE TEAM:

- ☐ THE NAME OF THE PROCEDURE RECORDED

- ☐ THAT INSTRUMENT, SPONGE AND NEEDLE COUNTS ARE CORRECT (OR NOT APPLICABLE)

- ☐ HOW THE SPECIMEN IS LABELLED (INCLUDING PATIENT NAME)

- ☐ WHETHER THERE ARE ANY EQUIPMENT PROBLEMS TO BE ADDRESSED

- ☐ SURGEON, ANAESTHESIA PROFESSIONAL AND NURSE REVIEW THE KEY CONCERNS FOR RECOVERY AND MANAGEMENT OF THIS PATIENT

THIS CHECKLIST IS NOT INTENDED TO BE COMPREHENSIVE. ADDITIONS AND MODIFICATIONS TO FIT LOCAL PRACTICE ARE ENCOURAGED.

The Checklist divides the operation into three phases, each corresponding to a specific time period in the normal flow of a procedure — the period before induction of anaesthesia (Sign In), the period after induction and before surgical incision (Time Out), and the period during or immediately after wound closure but before removing the patient from the operating room (Sign Out). In each phase, the Checklist coordinator must be permitted to confirm that the team has completed its tasks before it proceeds further. As operating teams become familiar with the steps of the Checklist, they can integrate the checks into their familiar work patterns and verbalize their completion of each step without the explicit intervention of the Checklist coordinator. Each team should seek to incorporate use of the Checklist into its work with maximum efficiency and minimum disruption, while aiming to accomplish the steps effectively.

Nearly all the steps will be checked verbally with the appropriate personnel to ensure that the key actions have been performed. Therefore, during **"Sign In"** before induction of anaesthesia, the person coordinating the Checklist will verbally review with the patient (when possible) that his or her identity has been confirmed, that the procedure and site are correct and that consent for surgery has been given. The coordinator will visually confirm that the operative site has been marked (if appropriate) and that a pulse oximeter is on the patient and functioning. The coordinator will also verbally review with the anaesthesia professional the patient's risk of blood loss, airway difficulty and allergic reaction and whether a full anaesthesia safety check has been completed. Ideally the surgeon will be present for "Sign In", as the surgeon may have a clearer idea of anticipated blood loss, allergies, or other complicating patient factors. However, the surgeon's presence is not essential for completing this part of the Checklist.

For **"Time Out"**, each team member will introduce him or herself by name and role. If already partway through the operative day together, the team can simply confirm that everyone in the room is known to each other. The team will pause immediately prior to the skin incision to confirm out loud that they are performing the correct operation on the correct patient and site and then verbally review with one another, in turn, the critical elements of their plans for the operation using the Checklist questions for guidance. They will also confirm that prophylactic antibiotics have been administered within the previous 60 minutes and that essential imaging is displayed, as appropriate.

For the **"Sign Out"**, the team will review together the operation that was performed, completion of sponge and instrument counts and the labelling of any surgical specimens obtained. It will also review any equipment malfunctions or issues that need to be addressed. Finally, the team will review key plans and concerns regarding postoperative management and recovery before moving the patient from the operating room. Having a single person lead the Checklist process is essential for its success. In the complex setting of an operating room, any of the steps may be overlooked during the fast-paced preoperative, intraoperative, or postoperative preparations. Designating a single person to confirm completion of each step of the Checklist can ensure that safety steps are not omitted in the rush to move forward with the next phase of the operation. Until team members are familiar with the steps involved, the Checklist coordinator will likely have to guide the team through this Checklist process.

A possible disadvantage of having a single person lead the Checklist is that an antagonistic relationship might be established with other operating team members. The Checklist coordinator can and should prevent the team from progressing to the next phase of the operation until each step is satisfactorily addressed, but in doing so may alienate or irritate other team members. Therefore, hospitals must carefully consider which staff member is most suitable for this role. As mentioned, for many institutions this will be a circulating nurse, but any health professional can coordinate the Checklist process.

Further detail on running the Checklist can be found at http://www.who.int/patientsafety/safesurgery/tools_resources/SSSL_Manual_finalJun08.pdf

PROMOTING A SAFETY CULTURE

"The safety steps should inspire effective change that will bring an operating team to comply with each and every element of the Checklist."

Modifying the Checklist

The Checklist can be modified to account for differences among facilities with respect to their processes, the culture of their operating rooms and the degree of familiarity each team member has with each other. However, removing safety steps because they cannot be accomplished in the existing environment or circumstances is strongly discouraged. The safety steps should inspire effective change that will bring an operating team to comply with each and every element of the Checklist.

In order to ensure brevity, the WHO Surgical Safety Checklist was not intended to be comprehensive. Facilities may wish to add safety steps to the Checklist. Teams should consider adding other safety checks for specific procedures, particularly if they are part of a routine process established in the facility. Each phase should be used as an opportunity to verify that critical safety steps are consistently completed. Additional steps might include confirmation of venous thromboembolism prophylaxis

by mechanical means (such as sequential compression boots and stockings) and/or medical means (such as heparin or warfarin) when indicated, the availability of essential implants (such as mesh or a prosthetic), other equipment needs or critical preoperative biopsy results, laboratory results or blood type. Each locale is encouraged to reformat, reorder or revise the Checklist to accommodate local practice while ensuring completion of the critical safety steps in an efficient manner. Facilities and individuals are cautioned, however, against making the Checklist unmanageably complex.

Introducing the Checklist into the operating room
It will take some practice for teams to learn to use the Checklist effectively. Some individuals will consider it an imposition or even a waste of time. The goal is not rote recitation or to frustrate workflow. The Checklist is intended to give teams a simple, efficient set of priority checks for improving effective teamwork and communication and to encourage active consideration of the safety of patients in every operation performed. Many of the steps on the Checklist are already followed in operating rooms around the world; few, however, follow all of them reliably. The Checklist has two purposes: ensuring consistency in patient safety and introducing (or maintaining) a culture that values achieving it.

Successful implementation requires adapting the Checklist to local routines and expectations. This will not be possible without sincere commitment by hospital leaders. For the Checklist to succeed, the chiefs of surgery, anaesthesia and nursing departments must publicly embrace the belief that safety is a priority and that use of the WHO Surgical Safety Checklist can help make it a reality. To demonstrate this, they should use the Checklist in their own cases and regularly ask others how implementation is proceeding. If there is no demonstrable leadership, instituting a checklist of this sort may breed discontent and antagonism. Checklists have been useful in many different environments, including patient care settings. This WHO Surgical Safety Checklist has been used successfully in a diverse range of healthcare facilities with a range of resource constraints. Experience shows that with education, practice and leadership, barriers to implementation can be overcome. With proper planning and commitment the Checklist steps are easily accomplished and can make a profound difference in the safety of surgical care.

Pentazocine

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INTRODUCTION

In 1967 pentazocine became the first opioid agonist-antagonist to be introduced into clinical practice as an analgesic. It was hoped that pentazocine would prove to be a powerful analgesic, free of the side-effects of opioid narcotics, particularly avoiding drug dependency. In practice pentazocine has proved to be less effective than hoped, but it is still used widely in resource-poor countries.

CHEMISTRY

Pentazocine is a benzmorphan which is chemically related to morphine. It is a white or cream, odourless, crystalline powder. It consists of a racemic mixture of dextro- (d) and laevo- (l) isomers which is soluble in acidic aqueous solutions. Pentazocine hydrochloride is used for oral use and the lactate form is used for parenteral and rectal administration.

Molecular weight (free base)	321.9
pKa	8.7
Solubility in water	1 in 30
Chemical structure	$C_{19}H_{27}NO.HCl$

PHARMACODYNAMICS

The action of pentazocine is mainly due to its l-isomer and it is a potent analgesic with both an agonist and antagonist action at opioid receptors. It differs from morphine in that it is a weak antagonist at OP3 (μ) opioid receptors, with its analgesic action due to an agonist action on OP2 (κ) receptors which interrupts pain pathways in the spinal cord. It also has some agonist action at other receptors which may result in dysphoric side-effects. It has no anti-inflammarory or anti-pyretic function.

Given intravenously, estimates of its potency vary from one third to one quarter the strength of morphine. This ratio is similar with intramuscular use with 30 - 40 mg of pentazocine equivalent to 10 mg morphine. When given by mouth, the analgesic action of pentazocine is much weaker than morphine and is thought to lie somewhere between that of peripherally acting analgesics such as paracetamol and weak opioids such as codeine.

Other actions of pentazocine mirror those of other opioids including respiratory depression, cough suppression, miosis, decreased gastric emptying and constipation and increased smooth muscle tone in the uterus and bladder. However in normal use these effects are usually of little clinical significance.

In contrast to other strong opioid analgesics however, there is a dose-related systemic and pulmonary hypertension, increased left ventricular end-diastolic pressure and a rise in central venous pressure, probably as a result of a rise in plasma catecholamine concentrations. Pentazocine also increases renal plasma flow but no change in glomerular filtration rate is seen.

PHARMACOKINETICS

Absorption

Pentazocine is completely absorbed after oral administration with peak plasma concentration at about 1-3 hours and a mean plasma half-life of about 2 hours. However blood levels show considerable variation both within and between subjects due to extensive but variable pre-systemic (hepatic) elimination.

Oral bioavailability ranges from 11 to 32% in subjects with normal hepatic function. Regardless of route of administration, pain relief lasts 2-3 hours as a maximum.

Animal studies show rapid and widespread distribution in the liver, lungs, kidneys, muscle and brain following IV or IM administration.

Summary

This article describes the pharmacology and clinical uses of the opioid agonist-antagonist pentazocine. Pentazocine is widely used around the world despite its considerable side-effects and tendency to cause dependency. It still has a useful function to play in the management of moderate to severe pain when used intravenously or intramuscularly, but should not replace morphine or pethidine if available.

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Low levels are detected in organs other than the liver after oral administration due to pre-systemic elimination.

The apparent volume of distribution varies but indicates significant drug accumulation in some tissues. Plasma protein binding is also variable, but up to 50 % may be present in red blood cells. Placental transfer occurs, with mean cord blood levels in the region of 60-70 % of those in maternal blood.

Table 1. *Peak plasma concentrations*

Route of administration	Time to peak plasma concentration (minutes)
Intravenous	2-3
Intramuscular/ subcutaneous	15-30
Oral	60-90

As a result of extensive hepatic metabolism, less than 10 % of an oral dose appears unchanged in the urine, although in patients with cirrhosis a significant reduction in body clearance and a marked increase in bioavailability are seen.

Metabolism and elimination
Up to 10 % is excreted unchanged in the urine with 1-2 % in the faeces as a result of enterohepatic circulation. Both are independent of the route of administration. The remainder undergoes extensive hepatic metabolism, including conjugation with glucuronic acid and oxidation of the terminal methyl groups of the dimethylallyl side chain. The two principle metabolites found in the urine are the cis-alcohol metabolite (11 %) and the trans-carboxylic acid metabolite (40 %). Both are inactive.

An increased rate of metabolism due to enzyme induction has been reported in smokers and following nitrous oxide administration.

PHARMACEUTICAL PREPARATIONS
Trade names of pentazocine include Fortral, Talwin, Fortralgesic, Fortralin, Sosegon, Sosenyl, Pentgin and Liticon. Pentazocine is also available in combination with aspirin and paracetamol (acetaminophen).

DOSE AND PATIENT RESTRICTIONS
As with analgesics in general there is no consistent relationship between analgesic activity and plasma concentrations of pentazocine. However normal doses are set out in Table 3.

Adults
Oral administration is usually started at 50-100 mg every 3-4 hours; titrating dose and frequency of administration to pain relief with the total daily dose not exceeding 600 mg.

Starting treatment at night, and using frequent smaller doses in preference to less frequent large doses, helps to reduce the incidence of side effects. Rectal administration may give more prolonged analgesia than equivalent oral doses.

Table 2. *Pharmaceutical preparations of pentazocine*

Parenteral forms:	
1. Talwin injection (USA):	30mg/ml in 1 or 2ml ampoules, sterile cartridge needle units, 10ml multiple dose vials. Mixed in an aqueous solution of pH4-5 as pentazocine lactate. For IV, IM and subcutaneous injection.
2. Fortral injection (UK):	30mg/ml in 1 or 2 ml ampoules for IV, IM or subcutaneous use
Oral forms:	
1. Talwin-Nx (USA)	50mg pentazocine with 500mcg naloxone
2. Fortral tablets (UK)	25mg and 50mg pentazocine hydrochloride tablets
3. Talwin Compound	12.5mg pentazocine with 325mg aspirin (2 tablets three-four times daily)
4. Talacen (acetaminophen)	25mg pentazocine with 650mg paracetamol (1 tablet four hourly)
Rectal forms:	
1. Fortral suppositories	50mg pentazocine lactate
Generally preparations should be stored at room temperature and protected from light and freezing	

Table 3. *Dosing of pentazocine*

Route of administration	Dose	Interval	Total dose in 24 hour
Intravenous - inject undiluted by slow bolus	0.5 mg/kg or 30-40mg	3-4 hourly	not to exceed 360mg
Intramuscular - inject deep into well developed tissue	1.0 mg/kg or 30-60mg	3-4 hourly	not to exceed 360mg
Oral	50-100mg	3-4 hourly	not to exceed 600mg
Use subcutaneous injection only when necessary: severe tissue damage is possible at injection sites			

Children

Oral administration under the age of 6 years is not recommended. Some sources recommended avoiding pentazocine for children of 6-12 years, although other studies suggest 25 mg every 3-4 hours as a suitable dose. Children over 12 years may receive an adult dose.

Use in pregnancy

Safety has not been unequivocally established and penatzocine should be used with caution. Neonatal dependency has been reported in women who have taken 50-300 mg daily throughout pregnancy.

Pentazocine has not been demonstrated to pass into breast milk although monitoring is recommended if high doses are prescribed.

Use in the elderly

Although no specific problems have been identified, care is required with impairment of hepatic or renal function as it may predispose to increased toxicity.

THERAPEUTIC USE

Postoperative pain

Pentazocine is a controlled drug in the UK and is prescribed parenterally for moderate to severe acute postoperative pain. In these circumstances 30-60 mg by IM or SC injection has a similar analgesic action to 10 mg morphine or 100 mg pethidine (meperidine).

In comparison to morphine or pethidine, the duration of action of pentazocine is slightly shorter. It has been claimed that pentazocine produces a lower incidence of side-effects in postoperative patients compared with morphine and pethidine, in particular nausea and vomiting, sedation and hypotension. However the side-effects of pentazocine are dose-related and overall the incidence and severity of side-effects at equivalent analgesic doses are similar with all three drugs.

Oral pentazocine is not a strong analgesic. While some comparisons show it to be as effective as codeine or dihydrocodeine, other studies have shown aspirin to have a greater analgesic effect than pentazocine. It is clear that the duration of analgesia produced by pentazocine is about 3 hours.

Chronic Pain

The usefulness of oral pentazocine in chronic pain is limited by its weak and unpredictable analgesic activity, dose-related (particularly psychomimetic) side-effects and its ability to antagonise the effects of pure opioid agonists if used concurrently.

Obstetrics

Pentazocine appears to be an effective analgesic during labour. There is some evidence that uterine activity may be increased and, compared with pethidine, the second stage of labour may be shortened. However there is no advantage with regard to side-effects; respiratory depression is comparable to pethidine in both the mother and the neonate.

Renal and biliary colic

Pentazocine may be used for the relief of acute pain of renal or biliary colic and has been shown to cause less smooth muscle contraction in renal and biliary tracts that morphine. However another study has shown a significant rise in intrabiliary pressure so that its use may be best avoided if other drugs are available.

Myocardial infarction

Pentazocine is an effective analgesic post myocardial infarction and may cause a rise in systolic blood pressure in contrast to the hypotensive effect of other opioids. However the associated rise in pulmonary artery pressure, left ventricular end-diastolic pressure and left ventricular minute work is potentially hazardous as it may lead to an increase in myocardial oxygen demand and extension of the infracted area. An alternative opioid analgesic is generally preferred.

Intravenous anaesthesia and premedication

There have been attempts to use pentazocine for intravenous anaesthesia and as a premedicant prior to general anaesthesia. However it confers no advantage over standard drugs and is generally only used when other drugs are not available.

CONTRAINDICATIONS

1. Respiratory depression
2. Raised intracranial pressure
3. Arterial or pulmonary hypertension
4. Pre-existing opioid dependency
5. Porphyria

Respiratory depression

This is mainly found with the l-isomer and in equipotent doses to that seen with morphine. Care is required in patients with impaired respiratory drive. Transient apnoea may occur in the neonate following its use in labour.

Raised intracranial pressure

Pentazocine increases intracranial fluid pressure in patients with an acute brain injury or when ICP is already increased due to a space-occupying lesion. However these changes are not seen in normal patients or in patients ventilated after a head injury, suggesting that mild respiratory depression with an associated intracranial vasodilatation from a rise in $PaCO_2$ may be the underlying cause.

Arterial or pulmonary hypertension

Pentazocine increases both heart rate and systolic blood pressure to a variable and unpredictable degree and should be avoided in patients with hypertension. IV doses of 30-60mg may cause an increase in pulmonary artery pressure with an associated increase in left ventricular end-diastolic pressure and their use should also be avoided. An increase in central venous pressure has also been reported but little consistent effect on systemic vascular resistance, cardiac output, stroke volume or coronary perfusion has been found.

Pre-existing opioid dependency

Withdrawal effects may occur in patients with opioid dependency due to its opioid antagonistic action.

Porphyria

Pentazocine has been found to be porphyrogenic in rats and on this basis is not recommended for use in patients with porphyria.

ADVERSE REACTIONS

Despite hopes that pentazocine would have less severe side-effects than pure μ-receptor agonists, this has not been the case in practice.

Life threatening adverse effects

Respiratory depression - when used as an adjuvant to anaesthesia in patients with chronic respiratory insufficiency.

Agranulocytosis - latency of 4-24 weeks from exposure to the drug. Although fatalities have been reported most cases are reversible on withdrawing the drug.

Severe or irreversible adverse effects

Epileptic seizures - rare and most often associated with high dose IV use during anaesthesia, or if there is an underlying intracranial pathology.

Addiction - although not considered addictive when first introduced, its potential for abuse has been increasingly recognised, particularly for the IV formulation which has resulted in greater control over its prescribing. As a consequence pentazocine-only tablets have been withdrawn in the USA in favour of one in combination with naloxone. Although naloxone is ineffective when given orally it is effective when injected IV.

Withdrawal symptoms are usually mild and include anxiety, dysphoria, tremor, sweating and musculoskeletal pains.

Pruritis - stinging, flushing when given IV. Repeated IM injections may cause soft tissue induration, fibrosis or ulceration, hyperpigmentation and a myopathy which, if severe, may impair movement resulting in contractures (more often associated with drug abuse rather than therapeutic use.

Symptomatic adverse effects

They are often dose-related, mild and self-limiting but can be severe:

- Psychotomimentic effects in 20% of patients. Includes disturbed dreams, auditory or visual hallucinations, euphoria and depersonalisation. Naloxone may be effective.
- Sedation, light headedness, vertigo
- Nausea and vomiting
- Other opioid side-effects include sweating, hot flushes, dry mouth, urinary retention
- Blurred vision, nystagmus, diplopia, miosis
- Headaches, chills and fever.

ACUTE OVERDOSE

Deaths due to pentazocine alone are rare. The main clinical features are respiratory depression, tachycardia and hypertension. Status epilepticus, coma, acidosis, respiratory depression, profound hypotension and ventricular arrhythmias can also be found.

Treatment is IV naloxone, a competitive antagonist at the opioid receptors, mediating the respiratory depression and maintaining respiration. Dose given is 0.1 mg repeated at 2-minute intervals according to the clinical state of the patient. 0.4-2 mg is sufficient in most cases although higher doses of 15-20 mg have been known to be required. An infusion of naloxone may be required.

OTHER EFFECTS

No significant biochemical effects have been recognised. No interference with clinical pathology tests. IM injections may increase creatine kinase levels.

DRUG INTERACTIONS

- **Halothane** - increases respiratory depression and hypotensive effects.
- **Anticoagulants** - may increase anticoagulant effect of both heparin and oral coumarins (e.g. warfarin).
- **Lignocaine** - prior administration enhances respiratory depressant effect of pentazocine.
- **CNS depressants** - increased sedation.
- **Opioid analgesics** - withdrawal effects if opioid dependency.
- **Monoamine oxidase inhibitors** - increased toxicity in mice although not demonstrated in humans.
- **Barbiturates** - do not mix in the same syringe as precipitation will occur.

CONCLUSION

Pentazocine was introduced in the hope that it would provide pain relief for moderate to severe pain without the side-effects of morphine. Unfortunately the reality has been disappointing. Although 30 mg of IM or IV pentazocine is comparable to 10 mg morphine, it has a more variable efficacy than morphine and its side-effects are still considerable, particularly the potential for dependency. This almost certainly accounts for the decrease in its use in the United Kingdom. Despite its removal from the WHO guide of essential drugs, it is still widely used in some poorly-resourced countries.

In summary, pentazocine still has a useful function to play in the management of moderate to severe pain when used intravenously or intramuscularly but should not replace morphine or indeed pethidine if available.

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Malignant hyperthermia

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Summary

Malignant hyperthermia (MH) is a rare but potentially fatal condition triggered by suxamethonium or an anaesthetic vapour. Early recognition of signs and prompt treatment are essential. The pathophysiology, clinical features and treatment of MH are described, with an emphasis on management and prevention in poorly-resourced settings.

INTRODUCTION

Malignant hyperthermia (MH) is a rare condition that was first recognised in the 1960s when a young man presenting for repair of a fractured tibia and fibula was more concerned about the anaesthesia than the operation. It transpired that 10 of his relatives had died following anaesthesia with ether. He subsequently went on to have a mild reaction to halothane anaesthesia.[1] Analysis of the family tree of this patient indicated an abnormal response to anaesthesia that was inherited via a dominant gene with incomplete penetrance. Much has been elucidated about MH since that time. There is good understanding of the cellular basis for MH, there is a specific treatment agent (dantrolene), an in vitro test for susceptibility to the condition has been developed and the specific gene defect has been identified. However, MH remains a condition that has the potential to be rapidly fatal in an otherwise fit and healthy individual. Anaesthetists should be aware of the diagnosis and treatment of this condition, the need to avoid specific trigger agents, and they should be able to provide safe anaesthesia for a patient who is susceptible to MH.

The actual incidence of MH cases has been reported to be between 1:5,000 and 1:50,000-1:100,000 general anaesthetics, but the prevalence of susceptibility to MH is felt to be much higher at about 1:3,000.[2] Due to its genetic basis, the prevalence of MH susceptibility varies around the world, and case reports or series have been reported for most ethnic groups including black Africans,[3,4,5] Thai,[6] Chinese,[7,8] Japanese[9] and Brazilians.[10]

PATHOPHYSIOLOGY OF MALIGNANT HYPERTHERMIA

The primary problem in MH is an inherited disorder of calcium handling in the sarcoplasmic reticulum of skeletal muscle. The genetic defect is found on the gene encoding the intracellular ryanodine receptor, responsible for calcium release in skeletal muscle cells. In response to potent volatile anaesthetics and depolarising muscle relaxants the uncontrolled release of intracellular calcium leads to muscle rigidity, a hypermetabolic state and a build up of the breakdown products of skeletal muscle.

When suxamethonium is used, the first sign may be masseter spasm, where the jaw is clenched tightly after administration, preventing intubation or airway manoeuvres. Not all cases of masseter spasm will go on to develop MH, but all should be treated with a high degree of suspicion. If possible, further investigation for MH in all cases of masseter spasm is advised, since some will prove to have susceptibility despite the lack of a subsequent reaction.

Without treatment, MH can lead to multi-organ failure and death. Muscle breakdown products accumulate (rhabdomyolysis), leading to hyperkalaemia and myoglobinuria. Enzymes from skeletal muscle can cause renal failure, cardiac failure and disseminated intravascular coagulation. Renal failure exacerbates the hyperkalaemia and acidosis from rhabdomyolysis. The combination of hyperkalaemia, acidosis and hyperthermia lead to a high risk of fatal myocardial arrhythmias. Otherwise, renal failure as a consequence of rhabdomyolysis may prove to be fatal, particularly where there are no facilities for renal replacement therapy.

Initially mortality from MH was about 80%. Improved recognition and improvements in anaesthetic monitoring have helped to reduce mortality. Outcomes have improved significantly since the introduction of dantrolene, a specific treatment for MH, with no deaths reported in a series of New Zealand cases since dantrolene became available in 1981.[11] Mortality in countries

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with limited access to dantrolene may still be significant, with a mortality of 25.8% in Taiwan between 1994 and 2004.[12]

MH is linked to some rare myopathies. Central core disease (CCD), a rare non-progressive autosomal dominantly inherited myopathy has been shown to be linked to RYR-1 mutations in 93% of Japanese patients.[2] Patients typically present in infancy with hypotonia and proximal muscle weakness. CCD is closely linked to MH susceptibility by in-vitro contracture testing. However, the link is variable, and there are other rare mutations associated with central core disease.

CASE SCENARIO

A 24-year-old male of Maori origin presented for open appendicectomy as an emergency. The patient had no past medical history of note, no previous anaesthetics and denied any family history of anaesthetic complications.

A rapid sequence induction was performed with alfentanil, thiopentone and suxamethonium. Intubation was awkward with some muscle tension noted, but not overt masseter spasm.

Mechanical ventilation was instituted, but relatively high pressures were required for ventilation and the end-tidal (ET) CO_2 rose to 9-10.5kPa (70-80mmHg). The patient's pulse was 70-80bpm and the blood pressure was stable at 100-120mmHg systolic. Nasopharyngeal temperature was 36.5°C.

Ventilation was increased but $ETCO_2$ increased to 12kPa (90mmHg). His temperature increased to 37.5°C over half an hour. The surgeon commented on a degree of muscle tension despite neuromuscular blockade with rocuronium. Anaesthesia was completed with intravenous propofol, the soda lime and circuit were changed, surgery was expedited and cold packs were applied to groin and axillae. The MH trolley was brought into theatre and senior help was summoned. The mixing of the first dose of dantrolene was commenced.

There was no further rise in $ETCO_2$ or temperature. An initial arterial blood gas showed supranormal oxygenation, respiratory acidosis with metabolic compensation and a lactate less than 2.0. The $ETCO_2$ at this point had fallen to 60mmHg (9kPa). The decision was therefore taken not to administer dantrolene and to wake the patient. He was extubated awake and kept in recovery for about 1 hour, where he complained of generalised muscle pains. He was then transferred to the High Dependency Unit. Initial bloods showed normal renal function and full blood count, with a creatine kinase (CK) of 25,000iu.l^{-1}. Urinary myoglobin was positive and he was treated with hydration and alkalinisation of urine. By the morning CK had risen to 30,000iu.l^{-1}, but settled over the following three days, after which he was discharged to the ward. He was given verbal and written instructions regarding malignant hyperthermia and referred for testing at a regional centre. Testing at 6 months post-event showed a strongly positive contracture test to both halothane and caffeine.

Also associated with MH are myotonia fluctuans, Multiminicore disease, Multiminicore myopathy, King Denborough syndrome and hypokalaemic periodic paralysis.[2]

CLINICAL FEATURES
Immediate changes
The presentation of MH is variable, but if a patient develops the signs of a hypermetabolic state or abnormal muscle rigidity under anaesthesia, then this should lead the anaesthetist to have a high index of suspicion.

Masseter spasm may be a herald of MH in patients administered suxamethonium, but not all patients with masseter spasm develop MH. For those who do not have masseter spasm, a rise in end-tidal CO_2 ($ETCO_2$) is normally the first sign. Tachycardia or tachyarrhythmia may be the first sign in the absence of $ETCO_2$ monitoring.

A rise in temperature typically occurs later, but at least two patterns are demonstrated, either an early rapid rise in temperature over a period of minutes, or alternatively a slow rising temperature which becomes apparent after about an hour. The temperature may rise more than 2°C per hour in fulminant MH.[2]

Other features of MH include:
- *Muscle rigidity* unaffected by neuromuscular blockade.
- *Cyanosis* develops with an increased oxygen extraction ratio. Oxygen consumption may increase up to threefold leading to cellular hypoxia despite a supranormal oxygen delivery. Increased end-tidal (i.e. alveolar) CO_2 leads to displacement of oxygen in the alveolus, as described by the alveolar gas equation ($P_AO_2 = PiO_2 - [P_ACO_2/R]$), reducing alveolar O_2 despite an adequate FiO_2.
- *Arrhythmias* – predominantly ventricular.
- Hypoxia, hyperkalaemia, metabolic acidosis and hypocalcaemia.

Late complications
Later complications are a result of rhabdomyolysis. Patients can go on to develop multi-organ failure as a result of a combination of rhabdomyolysis, electrolyte abnormalities and hyperthermia, leading to death.

Malignant hyperthermia may not be identified during a first anaesthetic and commonly presents during a second or third anaesthetic.

DIFFERENTIAL DIAGNOSES OF MALIGNANT HYPERTHERMIA
Other causes of a hypermetabolic state should be considered in the differential diagnosis:

- **Sepsis**.
- **Thyroid storm**.
- **Neuroleptic malignant syndrome** presents with hyperthermia and rigidity, typically developing hours to days after introduction of a neuroleptic drug. The pathogenesis is related to central dopamine handling rather than peripheral calcium channel effects. Treatment consists of a dopamine agonist (L-dopa or bromocriptine), but dantrolene may be required.

TREATMENT

A high index of suspicion for the diagnosis is important, as the management of malignant hyperthermia is dependant on early detection. On suspicion of MH, treatment should be instituted immediately, prior to confirmatory tests.

Effective treatment requires the immediate withdrawal of trigger agents (volatile agents), the administration of dantrolene, and the quick and effective actions of a well-trained team. Assistance is required for the management of such a rapidly deteriorating patient, including for the mixing of dantrolene, which is time-consuming.

Treatment falls into **immediate management** to halt the process and treat the immediate metabolic effects of MH, **ICU management** to continue resuscitation, manage the effects of rhabdomyolisis and observe for complications and **further management** aimed at investigation and advice for both patient and family.

Immediate management
Removal of trigger agents
Volatile anaesthesia should be discontinued and no further doses of suxamethonium should be used (particularly when masseter spasm is encountered at rapid sequence induction). A high fresh gas flow, preferably 100% O_2 should be used to flush the anaesthetic machine and ideally the breathing circuit should be replaced with a clean circuit. Anaesthesia will need to be maintained with intravenous agents (ketamine, thiopentone, propofol and opiates are all safe to use). The end of surgery should be expedited in order to focus on the management of MH.

Muscle relaxation
Non-depolarising muscle relaxants such as pancuronium or vecuronium are ineffective in reducing muscle contraction in MH as the pathology is intracellular. Dantrolene has an inhibitory effect on the ryanodine receptors on the sarcoplasmic reticulum of skeletal muscle, inhibiting calcium ion release. It is a specific antagonist to the MH process. Powder for reconstitution contains mannitol and sodium hydroxide to enhance solubility and increase pH. The Association of Anaesthetists of Great Britain and Ireland (AAGBI) guidelines

suggest a dose of 2-3mg/kg initially, followed by 1mg/kg up to every 10 minutes as required to reduce muscle contraction.[13] It is time-consuming to mix dantrolene so it is advisable that this role is delegated.

In the absence of dantrolene, treatment will be predominantly supportive, removing trigger agents and concentrating on the cooling measures described below.

Cooling
Active cooling is likely to be necessary, particularly where dantrolene is not available, but vasoconstriction by excessive cooling of the peripheries should be avoided. Active warming devices such as hot air mattresses can be converted to cooling mode, cold intravenous fluids should be used and consideration should be given to cold bladder irrigation and cold peritoneal lavage, particularly if the abdomen is already open as part of the surgery. Cold packs can be used, but should only be used in areas of high blood flow where tissue damage is less likely (not around the peripheral limbs). Sites where cold packs are placed should be inspected and duration of application should be limited.

Hypoxia and acidosis
The patient should be hyperventilated to, as close as possible, a normal pH. An adequate FiO_2 to maintain good oxygenation, despite the high metabolic demands, is needed – 100% oxygen is advisable initially. Sodium bicarbonate helps treat the acidosis and enhances the solubility of myoglobin by forced alkaline diuresis.

Rhabdomyolysis
Adequate hydration and alkalinisation of the urine help to solubilise myoglobin released from skeletal muscle, reducing the risk of renal failure. Aim for a urine output $>3ml.kg^{-1}.h^{-1}$ and a urine pH>7.0.[13]

Hyperkalaemia
Hyperkalaemia should be managed if serum potassium exceeds 6.5mmol/l or is felt to be contributing to arrhythmias.

- Polystyrene sulphonate resins (e.g. **calcium resonium**), 15g orally or 30g rectally, 6-8 hourly bind and remove potassium, but are relatively slow-acting in acute episodes.
- **Insulin** 15 units in 100ml of 20% **glucose** IV over 30-60 minutes drives potassium into the cells. (Roughly equivalent regimens using more or less concentrated glucose eg. 50ml of 50% glucose or 200ml of 10% glucose will have the same effect).
- **Bicarbonate** 50mmol IV leads to exchange of potassium for hydrogen ions across cell membranes and is particularly effective at reducing hyperkalaemia in the presence of acidosis.

- **Salbutamol** (a β_2-agonist) 5mg nebulised, 50mcg IV bolus or 5-10mcg/min IVI increases cellular uptake of potassium.
- **Calcium** 5-10ml of 10% calcium gluconate, or 3-5ml of 10% calcium chloride has a rapid onset, but a short duration of action, acting as a physiological antagonist to potassium.
- **Haemodialysis**, where available, may be required to clear potassium and for management of renal failure in some cases.

Cardiac arrhythmias

Sinus tachycardia with or without ventricular ectopic beats is common in MH, and may be the presenting feature. More serious arrhythmias can occur, especially VT and VF.

- **Procainamide** is useful for both ventricular and supraventricular arrhythmias and can be given IV at 25-50mg/min, up to a maximum of 1g. The ECG should be monitored for widened QRS and prolonged PR interval.
- **Magnesium sulphate** is useful for ventricular arrhythmias in a dose of 2g IV over 10 minutes.
- **Amiodarone** can be useful for both ventricular and supraventricular arrhythmias with a loading dose of 5mg/kg over 1 hour (roughly 300mg), followed by an infusion not exceeding 1.2g in 24h.

Calcium channel antagonists should be avoided in a MH crisis.

Disseminated intravascular coagulation

Conventional treatment with clotting factors (fresh frozen plasma, cryoprecipitate and platelets) as dictated by blood tests is used.

Management in ICU

Continuation of the treatments above is likely to be necessary, potentially including further doses of dantrolene for up to 24h. Care should be in a high dependency setting, where frequent monitoring can be continued, as well as intensive therapy. Reactivation can occur for up to 24h and active monitoring to detect this is necessary.

In addition to the above specific treatment, it is necessary to offer general supportive therapy and particularly to observe for and treat *renal failure* and *compartment syndrome*.

Compartment syndrome is a result of tissue damage in a limiting fascial sheath, with swelling and oedema leading to compression of the tissues and structures. High tissue pressures lead to further tissue necrosis and can obstruct blood flow to distal tissue.

- Common sites are calves and forearms.

- Presentation is often with intractable pain from tissue ischaemia (masked in unconscious patients).
- Other signs include
  - Tight tissues
  - Distal limb ischaemia
  - Absence of distal pulses
- Compartment pressures can be measured with a manometer, via a needle.
- Treatment consists of surgical fasciectomy

Further management

The patient should be referred to a specialist centre for MH testing if possible. If MH testing is not possible, the MH grading scale can be used to assess the likelihood of this having been a genuine episode of MH.[14] There is no strict cut-off to define the diagnosis, but, coupled with clinical judgement, the MH grading scale has been found to be useful. The scale is based on clinical and common biochemical markers and provides a likelihood range from almost never (0 points) to almost certain (50+ points). Marks are scored for rigidity, evidence of muscle breakdown, respiratory acidosis, temperature increase, cardiac involvement, family history and a miscellaneous section (acidosis and reversal with dantrolene). The validity of the scale has been questioned since the introduction of in vitro contracture testing into common use,[15] but no other clinical scale has been suggested as a replacement.

The patient and family should be counselled regarding the implications of MH. It is important that this is explained prior to discharge from hospital and this is the responsibility of the anaesthetic team.

With a diagnosis of MH there is a 50% chance of any parent, child or sibling having MH, and they should be appropriately counselled, and regarded as MH positive until negative testing is available. Aunts and uncles have a 25% chance and first cousins have a 12.5% chance of having MH. Accurate mapping in the absence of genetic testing can be difficult, but a detailed family history may help to elucidate the affected family. In the absence of testing, where there is a high suspicion of risk, the use of a volatile and suxamethonium-free anaesthetic should be seriously considered, and it would be wise to have a very high clinical suspicion for MH.

The gold standard test for MH is still the in vitro contractility test to halothane and caffeine. This requires a muscle biopsy to be taken under local anaesthesia (or using a trigger-free anaesthetic), six months after the event. Genetic testing is possible once the specific genotype is known from a family member. However, in order to definitively exclude MH susceptibility in a subject, in vitro contracture testing is still required.

ANAESTHESIA IN PATIENTS SUSCEPTIBLE TO MH

The key to anaesthesia in susceptible patients is to avoid the possible MH trigger agents, suxamethonium and volatile anaesthetics.

Due to the widespread use of volatile agents in theatres, it is important to ensure decontamination of the anaesthetic machine. A volatile-free machine can be kept in the theatre complex for such an occasion (and can also be used for critically ill patients in recovery), however, this is expensive and unnecessary. Alternatively, it is possible to ensure that the machine to be used is adequately cleared of volatile anaesthetic agents by flushing it through with 100% oxygen. The period required to flush the machine will depend on the machine used as well as the amount of componentry and circuitry changed. While the time required at 10 l/min may be as little as 5 minutes with some machines, after changing a large portion of the components, a minimum of 30 minutes seems wise, with 60 minutes of flushing appearing safe in almost all circumstances. If using a circle system, it is advisable to change the patient circuit and soda lime.

Black rubber absorbs anaesthetic vapours and should be changed to a fresh circuit prior to use for patients with known susceptibility to MH when possible, but a 20 minute flush with at least 8 l/min oxygen gives outflow concentrations of less than 5 ppm halothane in previously contaminated rubber circuits.[16] High fresh gas flows are required not only to flush the machine, but also to ensure volatile concentration doesn't subsequently rise. It should be noted that a recovery area with previously anaesthetised patients has been shown to have concentrations as high as 1 part-per-million halothane,[17] so complete exclusion of volatile is likely to be impossible.

Anaesthesia can be safely administered with intravenous agents and a non-depolarising agents such as vecuronium, pancuronium or rocuronium.

Where feasible for the planned surgery, spinal or regional anaesthesia are safe and appropriate techniques in patients who are MH susceptible, but safe emergency anaesthetic circuits and drugs should always be available for such a patient should general anaesthesia become necessary.

In addition to a trigger-free anaesthetic, it is important to monitor the patient carefully to detect possible activation of MH during anaesthesia or recovery. Monitors should include $ETCO_2$ during anaesthesia and temperature monitoring during anaesthesia and recovery.

A pre-prepared MH trolley (a station with the necessary equipment for dealing with MH, including dantrolene, sterile water, sodium bicarbonate and cooling packs) should be immediately available throughout the procedure and recovery. The duration of postoperative monitoring is controversial, however 1 hour in recovery appears to be a safe period, and for day surgery patients, a further one and a half hours prior to hospital discharge.

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Update in Anaesthesia

Anaesthesia for paediatric ear, nose, and throat surgery

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ADENOTONSILLECTOMY

Tonsillectomy is one of the most frequently performed surgical operations in children. According to the Department of Health Hospital Episode Statistics (http://www.hesonline.nhs.uk), 25 000 tonsillectomies and 6500 adenoidectomies were performed in children under 15 years of age in England in 2003.[4] The tonsils and adenoids are lymphoid tissues forming part of the Waldeyer's ring encircling the pharynx. They appear in the second year of life, are largest between 4 and 7 years of age and then regress. Children with adenotonsillar hypertrophy can present with nasal obstruction, recurrent infections, secretory otitis media and deafness (secondary to Eustachian tube dysfunction), and obstructive sleep apnoea (OSA). Tonsillectomy is indicated in children with recurrent tonsillitis if they have had five or more episodes of sore throat per year because of tonsillitis, or if symptoms have persisted for at least 1 year and are disabling, that is, interfering with normal functioning (SIGN publication no. 34, available from http://www.sign.ac.uk). Other indications for tonsillectomy include chronic tonsillitis, peritonsillar abscess, and OSA. Adenoidectomy is indicated when there is evidence of enlarged adenoids causing nasal obstruction, OSA, or hearing loss. In the presence of OSA, adenotonsillectomy eliminates obstruction in 85 – 95% of children, yielding improvement of symptoms and quality of life.

Preoperative assessment

Preoperative assessment should elicit features of OSA, especially in the younger child, in whom obstructive symptoms rather than recurrent infections are commonly the indication for surgery (prevalence of OSA 1 – 3%).

Symptoms of OSA include heavy snoring, apnoeas, restless sleep, extended neck position during sleep, and daytime hypersomnolence. Over time, this can lead to neurocognitive impairment, behaviour problems, failure to thrive, and rarely cor pulmonale.

Children with severe OSA have a higher incidence of perioperative complications and may need postoperative HDU/ICU care. Specifically, they are at an increased risk of desaturation, laryngospasm, and developing airway obstruction during induction of anaesthesia.[2] They have increased sensitivity to the respiratory depressant effects of sedatives and opioids and a diminished ventilatory response to CO_2 compared with normal.[2,3] The overall incidence of postoperative respiratory complications in children with severe OSA is 16 – 27% compared with an incidence of 1% in children without OSA. Other risk factors for respiratory complications include age >3 years, craniofacial abnormalities, neuromuscular disorders, failure to thrive, and obesity.[3]

Preoperative investigations are not routinely indicated for patients undergoing adenotonsillectomy (NICE Guideline on Preoperative Tests, available from http://www.nice.org.uk). It is difficult to confirm the diagnosis and quantify the severity of OSA. The gold standard for diagnosis is nocturnal polysomnography, but there is a great deal of variability in scoring methods between different sleep laboratories, and the test is expensive to perform.

Recent studies suggest that overnight oximetry to score the frequency and depth of desaturation events may be useful in identifying patients with severe OSA.[4] In children with long-standing OSA, a full blood count will reveal polycythaemia and an ECG may show a right ventricular strain pattern.

Summary

Children account for approximately one-third of all patients undergoing ear, nose, and throat (ENT) surgery. Procedures range from simple day-case operations, such as myringotomy, to complex airway reconstruction surgery undertaken in specialist centres. This article describes the anaesthetic management of some of the commonly performed paediatric ENT procedures, including adenotonsillectomy, oesophagoscopy, and middle ear surgery. Paediatric bronchoscopy has been dealt with in detail in an earlier article in this journal.[1]

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Anaesthetic considerations

The main areas of anaesthetic concern are airway management, provision of analgesia, and prevention of postoperative nausea and vomiting (PONV).

Airway management

Sharing the airway with the surgeon, remote access, and the need to prevent soiling of the respiratory tract are factors that need to be taken into consideration in airway management. Two techniques are commonly used: the tracheal tube and the reinforced laryngeal mask airway (LMA).[5,6] The advantages and disadvantages of these techniques are compared in Table1.

The tracheal tube provides a definitive airway, and a 'south-facing' RAE tube positioned in the midline provides good surgical access. The disadvantages of intubation are that muscle paralysis or a deep plane of anaesthesia are required, bronchial intubation or accidental extubation can occur with surgical movement of the neck, and there is variable protection against airway soiling. The dilemma of whether to extubate the patient when fully awake and able to protect their airway or still deeply anaesthetized to avoid a stormy emergence and bleeding always exists. The reinforced LMA offers a good airway with no soiling of the respiratory tract, avoidance of the use of neuromuscular blocking agents, smooth emergence, and airway protection until awake. To avoid soiling the laryngeal inlet, the LMA should be removed with the cuff still inflated. To ensure best surgical access, the smallest LMA for size should be used, and when positioned correctly, the cuff should not be visible once the Boyle-Davis gag has been opened to its fullest extent. An incorrectly sized LMA, or too large a blade on the mouth gag, can cause obstruction.

The main disadvantages of the LMA are that it does not offer the definitive airway provided by a tracheal tube and it may restrict surgical access in younger patients. However, with both the tracheal tube and the LMA, dislodgement or compression can occur during positioning of the mouth gag, and airway patency must be re-confirmed before surgery proceeds.

A postal survey of anaesthetic techniques used in paediatric tonsillectomy in the UK in 1996 – 7 suggested that only 16% of anaesthetists used the reinforced LMA routinely.[7] I.V. induction with propofol, tracheal intubation with succinylcholine, and spontaneous ventilation with isoflurane were the commonest anaesthetic techniques.[7] Concern about the danger of succinylcholine-induced hyperkalaemic cardiac arrest in children with undiagnosed muscle disease has led to a decline in the use of this drug for elective intubation. Alternative techniques for intubation include deep inhalation anaesthesia, combinations of propofol with a short-acting opioid, or the use of a short-acting non-depolarizing neuromuscular blocking agent during light anaesthesia.

Analgesia

Adequate postoperative analgesia is best provided with a combination of simple analgesics and small doses of opioids. Paracetamol[8] and NSAIDs have a morphine-sparing effect. The concerns around the potential for increased perioperative bleeding with NSAIDs have largely been discounted, with the exception of ketorolac, which should be avoided. Administering the simple oral analgesics before operation is safe and ensures effectiveness by the end of surgery.

Alternatively, the rectal route can be used after induction of anaesthesia. However, this route is less acceptable to many

Table 1. *Comparison of the LMA and the tracheal tube for tonsillectomy*

	LMA	Tracheal tube
Advantages	Straightforward airway	More secure airway
	No soiling of airway with blood	Good surgical access
	Smooth emergence	
	Paralysis not required	
	Airway protection until awake	
	Minimizes trauma to the airway	
Disadvantages	Less secure airway	Risk of airway trauma
	May impair surgical access	Oesophageal/bronchial intubation
		Requires paralysis
		Soiling of airway with blood
		Problems associated with extubation

patients and will not achieve therapeutic levels by the end of surgery in most cases. A single dose of dexamethasone $0.1 - 0.5$ mg.kg^{-1} has also been shown to reduce postoperative analgesic requirements, whereas local anaesthetic infiltration of the tonsillar bed has not been found to be superior to placebo. Regular doses of paracetamol and an NSAID after operation provide good analgesia.

Prevention of postoperative nausea and vomiting (PONV)

The incidence of PONV can be as high as 70% after adenotonsillectomy and a multimodal approach is indicated to combat this.

Minimizing starvation, avoiding the use of nitrous oxide (N_2O), and balanced analgesia with prophylactic administration of antiemetics reduce the incidence of PONV. A combination of ondansetron $0.1 - 0.2$ mg.kg^{-1} and dexamethasone $0.1 - 0.5$ mg.kg^{-1} (maximum 8mg) intraoperatively has been shown to greatly reduce the incidence of PONV.[9] Intraoperative fluid administration has also been shown to decrease the incidence of postoperative nausea. Rescue antiemesis can be provided by further doses of ondansetron with or without cyclizine $0.5 - 1$ mg.kg^{-1} (up to 50mg).

Special considerations

Severe OSA

In general, sedative premedication and long-acting opioids are best avoided in patients with severe OSA. Inhalation induction is preferred, as airway obstruction commonly occurs during induction, and children with associated craniofacial anomalies may prove to be difficult to intubate.[2] Consideration should be given to the use of a small dose of fentanyl to supplement simple analgesia, as this is associated with less postoperative respiratory depression.

The incidence of complications varies with the time of day that the procedure is performed. Children undergoing surgery in the morning have fewer desaturations than those undergoing the same procedure in the afternoon. Close postoperative monitoring and the availability of an ICU bed is required.

Day-case tonsillectomy

Successful and safe implementation of day-case tonsillectomy requires careful patient selection. Exclusion criteria include age >3 years, significant co-morbidity, OSA, and living further than a one hour drive from the hospital or having no private transport. Thought also needs to be given to the risk of early haemorrhage and the management of postoperative pain and PONV.

The incidence of early postoperative bleeding is <1% and the majority of these occur within the first 4h after surgery.

An extended observation period of $4 - 6$h before discharge is therefore recommended; this limits surgery to morning lists. A multimodal analgesic and antiemetic regimen as previously discussed is very important, as the main reasons for overnight admission are PONV, pain, and poor oral intake.

Bleeding tonsil

Haemorrhage is the most serious complication after tonsillectomy and can occur within the first 24h (primary haemorrhage) or up to 28 days after surgery (secondary haemorrhage). In the National Prospective Tonsillectomy Audit (July 2003 – September 2004), the incidence of post-tonsillectomy haemorrhage patients was 3.5% and the overall rate of return to theatre was 0.9%. The incidence of primary haemorrhage was 0.6% and the majority of these occurred within the first 6h after operation. Factors influencing haemorrhage rates were age (lower rates in children than adults), indication for surgery (highest rates with quinsy and recurrent tonsillitis, lowest with obstructive symptoms), and surgical technique (higher rates with use of diathermy and disposable equipment, lowest with blunt dissection).

The anaesthetic considerations in bleeding tonsil include hypovolaemia, the risk of pulmonary aspiration (swallowed blood with or without oral intake), potential for a difficult intubation because of excessive bleeding obscuring the view with or without oedema after earlier airway instrumentation, a second general anaesthetic, and the stress to both child and parents. Blood loss is because of venous or capillary ooze from the tonsillar bed and is difficult to measure, as it occurs over several hours and is partly swallowed.

Excessive blood loss may lead to the child spitting blood. In these cases, the child is likely to be seriously hypovolaemic, anaemic, and potentially difficult to intubate because of poor visualization of the larynx. Tachycardia, tachypnoea, delayed capillary refill, and decreased urine output are early indicators of hypovolaemia, whereas hypotension and altered sensorium are indicators of advanced volume depletion. Preoperative resuscitation (guided by trends in monitoring) is essential, even if this requires the insertion of an interosseous needle. Induction of anaesthesia in a hypovolaemic child can precipitate cardiovascular collapse. Haemoglobin and coagulation variables should be checked. Blood and blood products should be immediately available and transfused as necessary. Before induction, in addition to the standard equipment, a selection of laryngoscope blades, smaller than expected tracheal tubes, and two suction catheters should be immediately available. Anaesthesia is induced once the child is haemodynamically stable. Preoxygenation and rapid sequence induction with slight head-down positioning of the patient ensures rapid control of the airway and protection from pulmonary aspiration. Consideration should be given to adopting the left

lateral position if bleeding is excessive. Controlled ventilation provides good conditions for haemostasis.

Fluid resuscitation and transfusion of blood and blood products should continue intraoperatively as necessary. Once haemostasis is achieved, a large-bore stomach tube is passed under direct vision and the stomach emptied. Neuromuscular block is antagonized and the trachea is extubated, with the child fully awake in the recovery position. After operation, the child should be monitored closely for any recurrence of bleeding.

OESOPHAGOSCOPY
Rigid oesophagoscopy is performed for the removal of an ingested foreign body. History of ingestion, dysphagia, and odynophagia are the usual presenting symptoms, whereas a previous stricture is a predisposing factor for obstruction. The commonest site of impaction of the foreign body is at the level of the cricopharyngeus muscle. Oesophagoscopy should be performed in all cases of suspected impacted foreign body to prevent complications of perforation, mediastinitis, and fistula formation.

Anaesthetic considerations include management of the shared airway and the risk of pulmonary aspiration or oesophageal perforation during the procedure. A rapid sequence induction protects against pulmonary aspiration and ensures rapid control of the airway. The tracheal tube should be secured on the left side to allow easier access for the endoscopy. Adequate depth of anaesthesia and muscle relaxation during the procedure are essential to reduce the risk of oesophageal perforation. Analgesia is provided by a combination of intravenously or rectally administered simple analgesics and a small dose of opioid. The patient is extubated when fully awake. If oesophageal perforation is suspected, oral intake should be withheld, IV antibiotics commenced, and the patient closely observed for features of mediastinitis, such as severe chest pain, pyrexia, and subcutaneous emphysema.

EAR SURGERY
The most common surgical procedures on the ear are those performed to treat otitis media and its complications. Otitis media is the second most prevalent illness of childhood. This is because of a combination of factors including Eustachian tube dysfunction and an increased susceptibility to upper respiratory tract infection (URTI) in early childhood. The short Eustachian tube in young children predisposes to reflux of nasopharyngeal secretions into the middle ear space and thus to recurrent infections. Oedema of the Eustachian tube mucosa secondary to recurrent URTI, and mechanical obstruction of the Eustachian tube orifice by enlarged adenoids, lead to a negative pressure in the middle ear and a transudative effusion (secretory otitis media). Children with otitis media present with deafness and complications such as perforation, ossicular chain damage, and cholesteatoma. Surgery is performed to improve hearing and to eradicate middle-ear disease.

MYRINGOTOMY
Myringotomy and insertion of pressure-equalizing tubes are used to improve middle-ear aeration and hearing in chronic otitis media. It is a short procedure performed as a day-case. The preoperative assessment should elicit features of URTI, as otitis media is associated with recurrent URTI and these children can consequently have increased airway irritability. A small percentage of this population may also display symptoms of OSA secondary to adenoidal hypertrophy. The anaesthetic technique usually involves the patient breathing spontaneously via a facemask or LMA, with the head positioned to one side. Mild postoperative pain can occur in up to 75% of patients, but this can be avoided with the preoperative administration of paracetamol, NSAIDs, or both.[10]

MYRINGOPLASTY, TYMPANOPLASTY, AND MASTOIDECTOMY
Children with complications of chronic otitis media need more complex ear surgery. Myringoplasty involves repair of a tympanic membrane perforation in a dry ear. Tympanoplasty is performed when there is extensive middle-ear damage and involves reconstruction of the tympanic membrane and the ossicular chain. The approach to the ear can be permeatal or postaural, the latter providing better surgical access. Two surgical techniques of tympanic membrane grafting are used, the underlay and the overlay. The underlay technique involves elevation of a tympanomeatal flap and placing the graft material underneath (or medial to) the eardrum.

The overlay technique involves stripping the lateral epithelium off the eardrum and placing the graft material on the outer side of (or distal to) the eardrum. Various graft materials may be used, the most common being temporalis fascia, tragal perichondrium, and fat.

Mastoidectomy is performed to eradicate chronic suppurative middle-ear disease. The anaesthetic considerations associated with these three procedures are similar; therefore, we shall described their anaesthetic management collectively.

Anaesthetic considerations
Typically, these procedures are performed in the older child or teenager and can be of prolonged duration. The main factors that have a bearing on anaesthetic management are the effect of N_2O on the middle ear, the need for a bloodless operative field, the use of facial nerve monitoring by the surgeon, and the high associated incidence of PONV.

As the relative solubility of N_2O in blood is 34 times that of nitrogen, it diffuses across into the non-compliant middle-ear

cavity much more rapidly than nitrogen can leave. This can lead to pressures as high as 350 mm H_2O within 30 min of commencing N_2O, especially in the presence of Eustachian tube dysfunction.[11]

Displacement of tympanoplasty grafts, worsening of deafness, rupture of the tympanic membrane, and increased PONV have all been associated with elevated middle-ear pressures. In addition, after discontinuation of N_2O, rapid re-absorption of the gas leads to negative pressures in the middle ear and this can lead to 'lifting off ' of the underlay tympanic membrane graft. As the middle ear remains open until the surgeon places the graft over the tympanic membrane, N_2O can be used up to 10 – 15min before graft placement and then discontinued. However, it may be best to avoid its use in middle-ear surgery completely.

Any bleeding during middle-ear surgery distorts the view through the operating microscope and can make the procedure difficult. Venous ooze can be minimized by a head-up tilt of 10° – 15° and ensuring unimpeded venous drainage. Epinephrine infiltration by the surgeon, relative hypotension (mean arterial pressure 10 – 20%, normal), and avoidance of tachycardia minimize arterial bleeding.

In its course through the temporal bone, the facial nerve runs through the middle ear in close relation to the ossicles and through the mastoid before emerging from the stylomastoid foramen. Therefore, it is vulnerable to damage during middle-ear surgery, especially as the disease process can distort the anatomical relationship of the nerve to the ear structures and make identification difficult. Intraoperative facial nerve monitoring is useful for identification and preservation of the nerve during ear surgery. A single dose of a short-intermediate acting relaxant can be used to aid tracheal intubation, its effects should have worn off sufficiently before the stage in the operation when facial nerve monitoring is required. However, it may be prudent to avoid the use of relaxants altogether by using other agents to facilitate intubation or by avoiding intubation. Whether using a tracheal tube or an LMA, the patient requires controlled ventilation for this procedure. Much of the surgery is performed using an operating microscope; therefore, if paralysis is to be avoided, a deep plane of anaesthesia is required to guarantee immobility. Controlled ventilation also allows control of the end-tidal CO_2, which helps to minimize bleeding.

The options for airway management are a tracheal tube or a reinforced LMA. The advantages of a tracheal tube over an LMA are a secure airway and ease of controlled ventilation, though a stormy emergence contributing to graft displacement is a potential problem. Smoother emergence can be ensured by tracheal extubation in a deep plane of anaesthesia. A reinforced LMA has the potential advantages of less airway stimulation and smooth emergence, but care must be taken to limit airway inflation pressures in order to prevent gastric distension during controlled ventilation.

For either technique and where available, maintenance of anaesthesia with propofol and remifentanil, or sevoflurane and remifentanil, offers many advantages. They allow controlled ventilation without neuromuscular blocking agents, thus permitting unimpeded facial nerve monitoring. Remifentanil provides a titratable degree of hypotension while maintaining a stable heart rate and provides excellent operating conditions. The use of TIVA is also associated with a lower incidence of PONV.[12]

Analgesia and antiemesis

A multimodal approach provides good analgesia and minimizes opioid-induced PONV. Oral paracetamol and NSAIDs given before operation are better accepted by the older child; alternatively, these can be given rectally or intravenously during surgery. As remifentanil has no residual analgesic effect after termination of the infusion, a small dose of morphine should be given 30 – 40 min before the end of the procedure to ensure adequate analgesia on awakening. A greater auricular nerve block has been shown to reduce postoperative opioid requirement. Postoperative analgesia is provided by regular, simple analgesics and small doses of opioids if necessary.

Routine prophylactic ondansetron and dexamethasone are indicated because of the emetogenic potential of middle-ear surgery. Avoiding prolonged starvation, adequate hydration, avoiding N_2O, use of TIVA, and balanced analgesia also help decrease PONV.

BONE-ANCHORED HEARING AID

The bone-anchored hearing aid (BAHA) is a surgically implantable system for the treatment of conductive deafness in children with chronic ear infections or congenital external auditory canal atresia who cannot benefit from conventional hearing aids. It allows sound to be conducted through the bone rather than via the middle ear, a process known as direct bone conduction. The procedure involves two short operations. Firstly, a titanium fixture is implanted into the mastoid bone and this over time integrates with the bone of the skull. Around 6 months later, at a second operation, an external abutment is placed over the fixture and this allows a sound processor to be connected.

The majority of children presenting for BAHA implant have associated congenital anomalies, the commonest being Goldenhar's syndrome (26%) and Treacher Collins syndrome (21%).[13] There is also a high incidence of congenital heart disease (19%) and craniofacial anomalies. The main anaesthetic

concern is an increased incidence of difficult intubation. In most instances, after inhalation induction, the airway can be safely and easily maintained using a reinforced LMA. However, equipment for fibreoptic intubation and appropriately trained staff should be available in the event of a need for intubation. Analgesia is provided with a combination of paracetamol, NSAID, and a small dose of opioid. Routine antiemetics are indicated, as PONV is common.

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The Transversus Abdominis Plane (TAP) block: Abdominal plane regional anaesthesia

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Summary
TAP block involves deposition of local anaesthetic agent into the fascial plane superficial to the transversus abdominis muscle. This technique can be used for any surgery involving the lower abdominal wall, including bowel surgery, caesarean section, appendicectomy, hernia repair, umbilical surgery and gynaecological surgery. The relevant anatomy is described, followed by detailed descriptions of the landmark and ultrasound-guided techniques.

Regional anaesthesia is a rapidly evolving subspecialty area. Over recent years there has been growing interest in abdominal plane blocks, with promising data emerging on efficacy. The TAP block allows sensory blockade of the lower abdominal wall via local anaesthetic deposition above the transversus abdominis muscle.

HISTORY OF THE TAP BLOCK

Abdominal field blocks and costo-iliac block have been used in anaesthesia for surgery involving the anterior abdominal wall for several decades. A technique involving multiple injections of local anaesthetic in the abdominal wall was used in the 1980s.[1] This technique was improved with a blind landmark technique, via the 'lumbar triangle of Petit'.[2] The clinical efficacy of the landmark technique and, more recently, ultrasound guided techniques have been investigated in several centres around the world.[3,4]

ANATOMY

Innervation of the anterolateral abdominal wall arises from the anterior rami of spinal nerves T7 to L1. Branches from the anterior rami include the intercostal nerves (T7-T11), the subcostal nerve (T12), and the iliohypogastric and ilioinguinal nerves (L1). These give rise to lateral cutaneous and anterior cutaneous branches as they become more superficial.

The intercostal nerves T7 to T11 exit the intercostal spaces and run in the neurovascular plane between the internal oblique and the transversus abdominis muscles. The subcostal nerve (T12) and the ilioinguinal and iliohypogastric nerves (L1) also travel in the
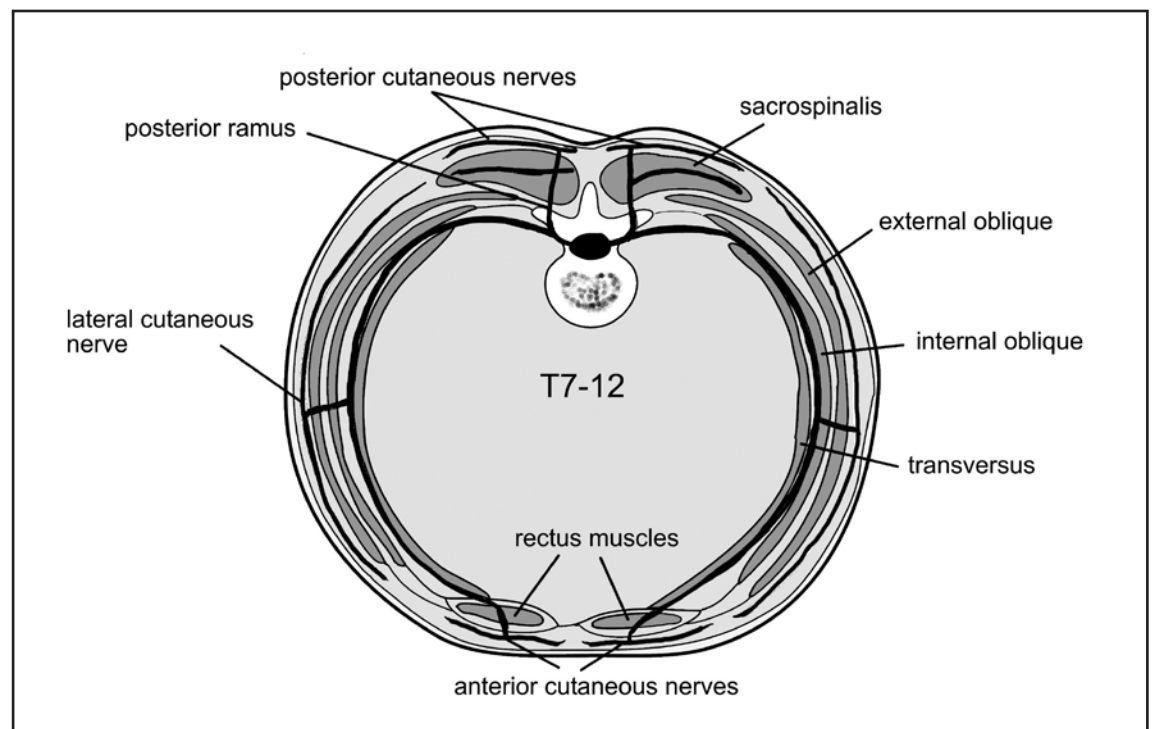

Figure 1. *Transverse section of the abdominal wall showing the path of nerves T7-T12 (left) and L1 (right) within the transversus plane*

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plane between the transversus abdominis and internal oblique, innervating both of these muscles. T7-T12 continue anteriorly from the transversus plane to pierce the rectus sheath and end as anterior cutaneous nerves. The thoracic nerves, T7 to T12, provide motor innervation to pyramidalis and the rectus muscle. These nerves have cutaneous branches laterally in the abdomen. T7-T11 provide sensory innervation to the skin, costal parts of diaphragm, related parietal pleura and the peritoneum. T7 gives sensory innervation at the epigastrium, T10 at the umbilicus, and L1 at the groin.[5,6]

CLINICAL APPLICATIONS

TAP block can be used for any surgery involving the lower abdominal wall. This includes bowel surgery, caesarean section, appendicectomy, hernia repair, umbilical surgery and gynaecological surgery. A single injection can achieve sensory block over a wide area of the abdominal wall. The block has been shown to be useful in upper abdominal surgery,[7] but the upper extent of the block and its use in upper abdominal surgery are
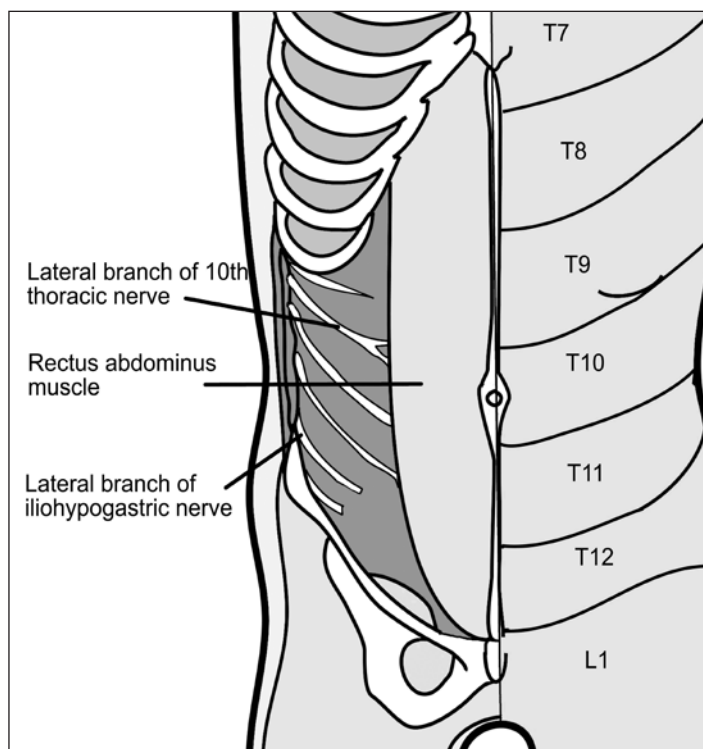
Figure 2. *Cutaneous nerve distribution and dermatomes of the abdominal wall*

controversial.[8,9,10,11] TAP block is particularly useful for cases when an epidural is contraindicated or refused.[3] The block can be performed unilaterally (eg. appendicectomy), or bilaterally when the incision crosses the midline (eg. Pfannenstiel incision). A single injection can be used, or a catheter inserted for several days of analgesic benefit. TAP block also has a role as rescue analgesia on awake postoperative patients who did not receive blocks prior to abdominal surgery.[12]

PERFORMING THE BLOCK

The principal of the block is to deposit local anaesthetic into the tissue plane between the internal oblique and the transversus abdominis. The two methods used include a blind technique, based on surface anatomy landmarks, and an ultrasound guided technique performed under direct vision. These methods are described below. The block takes up to 30 minutes to be effective so should be performed after induction and prior to surgery where possible. Intravenous opioid is required for skin incision and the early operative period as the block becomes established. TAP block for caesarean section is performed at the end of surgery and hence intravenous opioid will be required in the immediate post operative period while the block is becoming established.
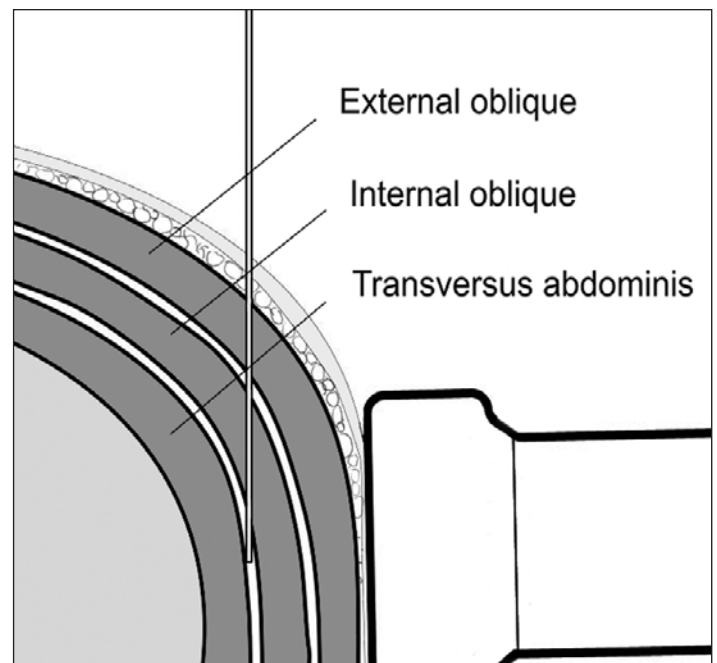

Figure 3. *Transverse section of the abdomen showing injectate deposition in the transversus plane*

Anaesthetic Agent

The volume of injectate is critical to success of TAP block. In an average sized adult 30ml of local anaesthetic should be used for unilateral block and 25-30ml used each side for bilateral block. Lignocaine, bupivacaine and ropivacaine have each been used for this block with success. Adequate volume is more important than using strong concentrations of local anaesthetic. The maximal safe dose of the chosen agent must be strictly adhered to. Examples of possible doses are shown in Table 1.

Landmark Technique

The landmark for palpation is the 'triangle of Petit' which lies above the pelvic rim in the midaxillary line (see Figure 4). The

Table 1. *Examples of appropriate drug selection for unilateral and bilateral TAP block based on patient weight*

	30kg	50kg	60-80kg
Unilateral (eg. Appendicectomy, hemicolectomy)	15ml: 0.5% ropivacaine or 0.375% bupivacaine	25ml: 0.5% ropivacaine or 0.375% bupivacaine	30ml: 0.5% ropivacaine or 0.375% bupivacaine
Bilateral - dose to each side (eg. LSCS, abdominal hysterectomy)	15ml: 0.25% ropivacaine or 0.25% bupivacaine	25ml: 0.25% ropivacaine or 0.25% bupivacaine	30ml: 0.25% ropivacaine or 0.25% bupivacaine

inferior border of the triangle is the iliac crest. The anterior border of the triangle is formed by the lateral edge of the external oblique muscle. The posterior border of the triangle is formed by the lateral edge of the latissimus dorsi muscle.[2,7,13] The triangle is tender to deep palpation in conscious patients.

The puncture site is just above the iliac crest and just posterior to the midaxillary line within the triangle of petit. A 24G blunt-tipped 50mm needle is inserted perpendicular to the skin, and a give or 'pop' is felt when the needle passes through the fascial extensions of the internal oblique muscle. The needle tip is therefore between the fascial layers of the external and internal oblique. Further advancement with a second 'pop' indicates that the needle has advanced into the fascial plane above transversus abdominis and, after aspiration, 25-30ml of local anaesthetic is injected.[2,7] There has been some controversy about seeking one or two 'pops' during the landmark technique of TAP block. Use of a 'two pop' technique is generally advocated and is supported by the cadaveric and imaging studies published to date.[14,15]

The triangle of Petit can be difficult to palpate, especially in obese patients. Rafi suggests a needle insertion point 2.5cm behind the highest point of the iliac crest when the triangle is not clearly palpable.[2] Requesting the patient to lift his head and shoulders from the supine position will contract the abdominal muscles and can assist palpation of the triangle.

Ultrasound Technique

The TAP block can be performed relatively easily with the use of ultrasound. A broadband linear array probe is used, with an imaging depth of 4-6cm. The ultrasound probe is placed transverse to the abdomen (horizontal plane) in the midaxillary line between the costal margin and the iliac crest. Three muscle layers are clearly seen in the image. A 100mm short bevel needle is used. The needle is inserted in a sagittal plane approximately 3-4 cm medial to the ultrasound probe. The point of needle insertion is closer to the probe in children and further from the probe for obese adults. For optimal imaging of the needle it should be held parallel to the long

Figure 4. *Surface anatomy labelled for landmark insertion of TAP block in an adult male in the supine position*

Figure 5. *Needle and probe position for ultrasound guided TAP block in an adult male in the supine position*

axis of the ultrasound probe (in plane technique). The probe is moved slightly anteriorly to image the skin puncture and superficial course, then gradually posteriorly to the midaxillary line position (shown in Figure 5), following the needle to the correct position in the transverse abdominis plane.

Real time ultrasound imaging allows observation of the needle passage through the skin and subcutaneous tissue, then through the external and internal oblique muscles. The needle tip is directed into the plane below the internal oblique and above the transversus abdominis muscle. A small volume of local anaesthetic (1ml) will be seen to open the plane between the two muscles and can be followed by insertion of the full dose of local anaesthetic. If the 1ml dose appears to be
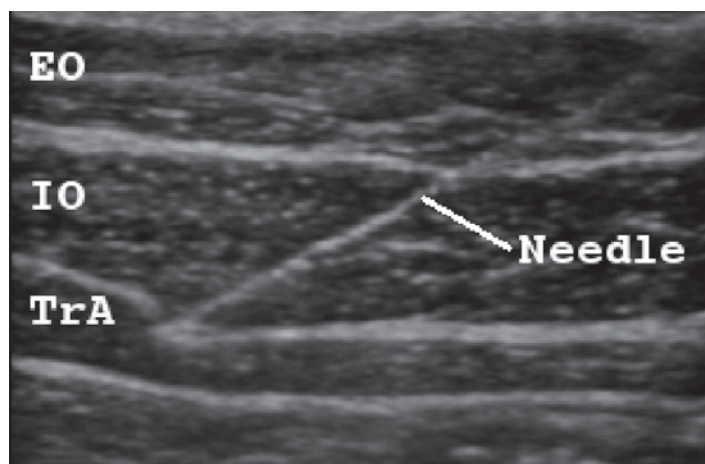
Figure 6. *Ultrasound image showing the muscle layers of the lateral abdominal wall with the needle seen positioned above the transversus abdominis muscle. EO: external oblique, IO: internal oblique, TrA: transversus abdominis*
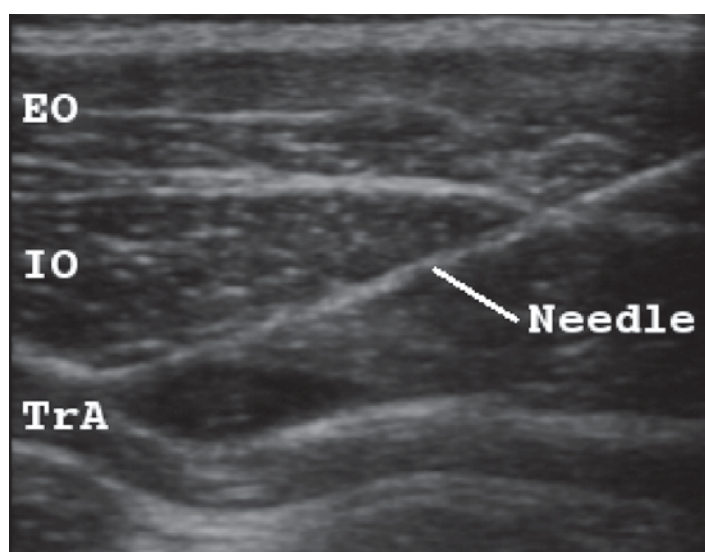

Figure 7. *Ultrasound image during initial injection of 5ml local anaesthetic. Injectate is in the transversus plane and alters the muscle layer appearance. EO: external oblique, IO: internal oblique, TrA: transversus abdominis*

within muscle rather than between them, needle adjustment is required. The local anaesthetic injectate appears hypoechoic (black compared to the muscle layers) on ultrasound imaging. When the needle tip is positioned correctly the injectate will be seen on ultrasound to spread out in the plane between the two muscles.[3] Ultrasound can also allow direct visualisation of structures in this region such as the deep iliac circumflex vessels and the iliohypogastric/ilioinguinal nerves.[16,17]

AREAS OF CONTROVERSY

There is debate in the literature regarding the extent of the sensory block achieved. Published investigators agree there is reliable block spread between L1 and T10 dermatomes. Initial publications found a block height from L1 to T7 could be achieved and hence the block was suitable for use in midline laparatomy.[9,11] Other investigators have found that the block does not reliably rise above the umbilicus and is therefore better suited to lower abdominal surgery only.[8,10] McDonnell and Laffey state that examining extent of the block prior to full spread could be misleading and measurement will be most accurate, when full block height has been achieved several hours after insertion of the block.[9] Some investigators have found the block height does not continue to extend over hours.[10] It may be that a different distribution of anaesthetic (and hence sensory blockade) occurs with the landmark technique compared to ultrasound-guided technique. Further anatomic studies are in progress to examine this issue.

EVOLVING DEVELOPMENTS IN TECHNIQUE

An alternative approach called the oblique subcostal TAP block has recently been described.[10] In this variation the ultrasound probe is held below and parallel to the costal margin, oblique to the sagittal plane. A 100-150mm needle is inserted at a position close to the xiphoid process and in plane to the ultrasound probe. The local anaesthetic is deposited between the transversus abdominis and rectus abdominis muscles, or between the rectus muscle and posterior rectus sheath (if there is no transversus at that level). The advantage of this approach is reliable spread of sensory block above the umbilicus (eg. for cholecystectomy).

LITERATURE REVIEW

In 2004, a report was published detailing a trial of the landmark TAP block procedure performed on both cadaveric specimens (methylene blue dye was used) and on healthy volunteers (radio-opaque dye with 0.5% lignocaine was used).[14] Cadaveric dissection revealed dye deposition in the transversus abdominis plane. CT imaging of live volunteers identified dye in the transversus abdominis neurovascular plane and pinprick testing indicated sensory block from L1-T8 dermatome.

Another cadaveric study was published by the same team of investigators in 2007.[15] This examined spread of methylene

blue dye injected via the angle of Petit using the landmark technique. The cadaveric dissection revealed reliable deposition of injectate into the transversus abdominis plane. In addition three healthy male volunteers were given a TAP block with radio-opaque dye and lignocaine to a final concentration of 0.5% and final volume of 20ml. 20 minutes after the block CT imaging demonstrated spread throughout the transversus abdominis plane. Sensory block assessment revealed a block from L1 to T7 which receded over 4 to 6 hours. A further three healthy male volunteers were given a TAP block of 1% lignocaine and radiopaque dye then MRI was performed at 1, 2 and 4 hours after the block. A gradual reduction in deposition of the injectate was demonstrated over time.

A small trial of TAP blocks performed on 12 open retropubic prostatectomy patients was reported in 2006.[18] The blocks were performed with 20ml of 0.375% bupivacaine to each side pre-operatively. Minimal morphine consumption was demonstrated (mean of 6.33mg at 48 hours with a range of 0-15mg). There were no adverse effects reported from the block.

In 2007, TAP block efficacy was examined in a randomised clinical trial of 32 patients undergoing large bowel resection via midline abdominal incision.[7] The patients were randomised to receive standard care (PCA, regular non-steroidal antiinflammatory drugs and paracetamol) or TAP block with the landmark technique (20ml 0.375% levobupivacaine). They found the TAP group had decreased visual analogue scale pain scores at emergence and at all times measured postoperatively up to 24 hours. There were no complications from the blocks

Figure 8. *Needle and probe position for ultrasound guided oblique subcostal TAP block (reproduced with kind permission from Dr P Hebbard)*

and a high reported patient satisfaction level in the TAP group.

Another randomised clinical trial from the McDonnell team in 2008 examined TAP block efficacy after caesarean section delivery.[19] Fifty elective patients for caesarean section (via spinal anaesthetic and Pfannenstiel incision) were randomised to receive TAP block (landmark method) versus placebo in addition to standard anaesthesia (paracetamol, diclofenac and intravenous morphine). The TAP block was performed at the end of surgery using 1.5mg/kg ropivacaine (to a maximal dose of 150mg). A blinded investigator assessed patients at specific time intervals between 2 to 48 hours postoperatively. Results showed TAP block reduced visual analogue pain scores and mean total morphine requirements in the first 48 hours (18mg versus 66mg in the placebo group). There were no complications from the blocks.

A second publication on use of TAP blocks after caesarean section describes placement of TAP catheters under ultrasound guidance in three case reports.[16] Continuous infusions of 0.2% ropivacaine at 4ml/h was used for 72 hours. The reported benefits of the block included low pain scores, minimal use of supplemental opioid and absence of nausea and vomiting.

A recent case report describes a complication relating to the blind landmark technique for TAP insertion.[20] A TAP block was performed on a woman for abdominal hysterectomy (50kg in weight and 160cm tall). At laparotomy, approximately 50ml of fresh blood was found in the abdomen, due to needle perforation of the liver. The liver was found to be enlarged and reached the right iliac crest. Authors of the report recommend palpation of the liver edge prior to block insertion, especially in people of small stature.

DANGERS AND LIMITATIONS

Regional anaesthesia in general has a very low rate of serious complications. The risk in regional anaesthesia varies with the type and location of the block. The head and neck for example, are sites of higher complication rates compared to the abdomen. General risks of regional blockade include: needle trauma, intraneural injection, neural ischaemia, inadvertent intravascular injection, local anaesthetic toxicity, infection, and poor/failed block.[17] The general risks for regional blockade are applicable to the TAP block, however the site of injection for the TAP block is relatively low risk. This review found only one published report of complication from the TAP landmark technique (as already described)[20] and could not identify any published cases of complications from the ultrasound-guided TAP block.

The landmark technique relies on the 'pop' sensation which some clinicians believe is an imprecise sign.[3] The identification
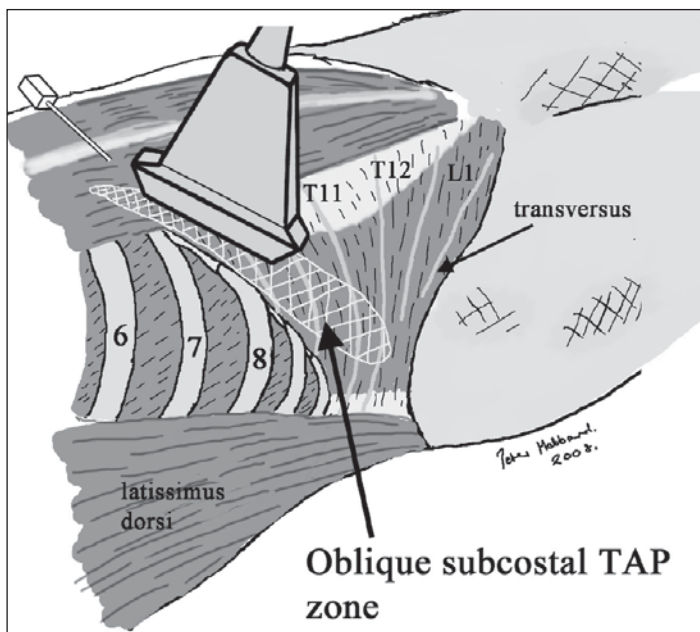
of the landmarks is more challenging in the obese hence the risk of peritoneal perforation is probably higher. If anatomy is abnormal, such as hepatomegaly, there is risk of damage from the needle puncture. Ultrasound techniques are likely to improve the safety of this block as the needle passage and injection can be followed in real time, however this has not been scientifically tested to date. Some authors argue that peritoneal perforation with a small gauge sterile needle is not likely to be significant.[21]

FUTURE DEVELOPMENTS

Ultrasound guidance for performance of this block has become the method of choice where available. We can look forward to further data being published on effects of the block and likely a wider range of possible techniques, particularly for targeting the upper abdominal wall. The ease with which this block can be performed, an excellent safety profile to date, and outstanding clinical utility, will no doubt lead to increasing popularity and use of the transversus abdominis plane block.

ACKNOWLEDGEMENTS

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Management of acute cervical spine injury

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INTRODUCTION

Between 2 and 5% of patients suffering from blunt polytrauma have a cervical spine injury. Cervical spine injuries tend to occur between 15 and 45 years and are seen more commonly in males (7:3). The most common level of fracture is C2 whereas dislocations occur most commonly at the C5/6 and C6/7 levels.[1]

The initial management of the polytrauma patient follows the Advanced Trauma Life Support (ATLS) practice of airway and cervical spine control, breathing and circulation. Assessment of injuries takes place initially in the form of a primary survey, during which time life-threatening injuries are excluded. This is followed by a secondary survey when a more detailed assessment of injuries is carried out, including spinal injuries. All polytrauma patients should be assumed to have a cervical spinal injury until proven otherwise; precautionary cervical spine immobilisation should be instigated for all patients at the scene of the injury by pre-hospital staff. By immobilising the spine immediately, major injuries can be treated at the scene, or on arrival at hospital, without the risk of disrupting an unstable cervical spine injury and causing secondary neurological injury.[2]

IMMOBILISATION OF THE SPINE

Until spinal injuries can be excluded or 'cleared' the spine must be immobilised and this can be achieved in a number of ways. However, all methods continue to allow varying degrees of movement. Soft cervical collars are the most inefficient and provide very little stability and therefore should not be used. Whereas the application of Gardner-Wells forceps can be considered the most effective technique it is rarely a practical solution in the acute setting. Two methods are in common use, compromising between simplicity of application and effectiveness: these are semi-rigid collars and manual in-line stabilisation (MILS). In the prehospital setting, MILS should be applied as an initial manoeuvre as the patient's airway is assessed and then, when available, a semi-rigid collar should be applied. Further stability is achieved by using sandbags or blocks on either side of the head, with two non-elastic self adhesive tapes strapped across the head and on to a rigid spinal board. Users should be aware of the disadvantages of semi-rigid collars (Table 1).

Laryngoscopy is more difficult with a semi-rigid collar in place. If laryngoscopy and intubation is urgently indicated the collar should be removed and MILS applied instead (Figure 1). During laryngoscopy MILS reduces cervical spine movement by up to 60%. An assistant squatting behind the patient applies MILS by placing his or her fingers on the mastoid processes and the thumbs on the temporoparietal area of the skull. The hands are then pressed against the spinal board and act to oppose movements of the head caused by the anaesthetist. Axial traction should not be applied because of the risk of exacerbating cervical spinal injuries. Until the spine is 'cleared' a log roll should be performed for any movement or transfer of the patient.[3, 4]

Table 1. *Disadvantages of semi-rigid collars*

Total immobilisation is not achieved

Increases the chance of difficult laryngoscopy

Can exacerbate cervical spinal injuries

Can cause airway obstruction

Can increase intracranial pressure (ICP)

Increases risk of aspiration

Increases risk of deep vein thrombosis (DVT)

May cause significant decubitus ulcers

Summary

This article covers the aspects of acute cervical spine injury that are relevant to anaesthetists. The anaesthetist's involvement will range from participating in the resuscitation of patients with polytrauma to the provision of safe anaesthesia to allow surgical treatment for cervical spine or other injuries. The importance of early immobilisation is emphasised and strategies used to 'clear' the cervical spine are described.

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Clearing the cervical spine

The exclusion of spinal injuries or 'clearance' requires the exclusion of both bony and ligamentous injuries, and ideally requires a combination of clinical assessment and radiological investigation. Clinical clearance of cervical spine injury is difficult or impossible in patients who are unconscious (due to sedation, anaesthesia or head injury) or have distracting injuries to other parts of the body. Anaesthetists should understand the principles of clearing the cervical spine, since a proportion of patients cannot be clinically cleared for several days and prolonged cervical spine immobilisation (with its inherent risks) may be necessary.

Figure 1. *(A) Application of manual in-line stabilisation (MILS). (B) Bimanual application of cricoid pressure*

Two sets of screening clinical criteria have been proposed prior to imaging the cervical spine, in an attempt to reduce the number of unnecessary X-rays. These are the Canadian C-spine rule and the National Emergency X-radiography Utilisation Study (NEXUS) criteria. Both are sensitive tools.[1] The NEXUS criteria include 'no evidence of posterior cervical tenderness', 'no history of intoxication', 'an alert patient', 'no focal neurological deficit' and 'no painful distracting injuries'. If all the criteria are fulfilled then the cervical spine can be cleared without the need for imaging.

If these screening tests indicate that radiological imaging is required, the strategy needed to clear the cervical spine differs depending on whether the patient is awake or unconscious. In the alert patient it is generally agreed that clearing the spine requires a 3-view plain X-ray series (lateral and AP cervical spine views with a 'peg view'), with a computerised tomogram (CT) for areas that cannot be visualised or are suspicious. If these are normal, but the patient is complaining of neck pain, a lateral cervical spine X-ray should then be performed in flexion and extension.

In the unconscious, since ligamentous injuries are difficult to exclude with accuracy using radiography, there is less agreement on the best method. Three options are available:

1. The cervical spine is left uncleared and the spine kept immobilised until the patient is fully conscious. Inherent with this method are the complications of immobilisation for any long duration, particularly decubitus ulcers.

2. Alternatively the patient has a combination of plain X-rays and CT scans to exclude bony injuries and, where available, this should be followed by magnetic resonance imaging (MRI) or fluoroscopy to exclude ligamentous injuries.

3. MRI may not be available and there are considerable practical difficulties associated with its use in unconscious critically-ill patients. A thin-cut CT scan is an alternative,

Figure 2. *Lateral cervical spine X-ray, showing fracture-dislocation of C4 (A) on C5 (B)*

including coronal and sagittal reconstruction of the entire cervical spine. Although less sensitive than MRI for the detection of ligamentous injury, CT is more practical and the number of unstable ligamentous injuries missed is extremely small.[1,3,5] It is worth remembering that the incidence of ligamentous injury without bony injury in blunt trauma is 0.02%.
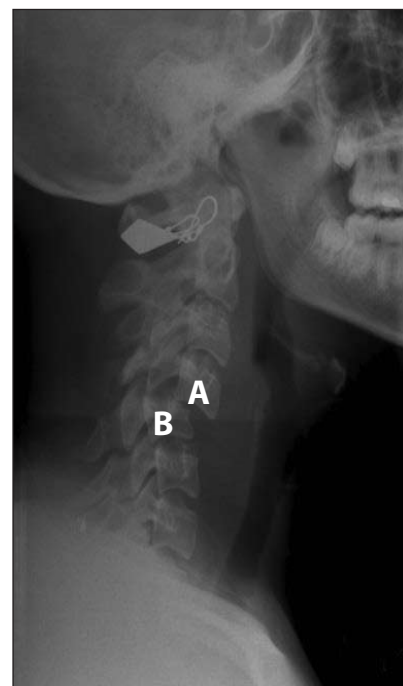
AIRWAY MANAGEMENT

Patients may require airway instrumentation as an emergency (for airway obstruction, respiratory failure or as part of the management of a severe head injury) or later in their management as part of anaesthesia for surgical management of other injuries.

The extent to which the injured cervical spine can be safely moved is unknown. Therefore the main aim during management of the airway, in patients with potential cervical spine injuries, is to cause the least amount of movement possible. All airway manoeuvres will produce some degree of movement of the cervical spine, including jaw thrust, chin lift

and insertion of oral pharyngeal airways. Mask ventilation is known to produce more movement than direct laryngoscopy.

Most anaesthetists are comfortable with direct laryngoscopy and oral intubation and it is therefore the obvious first choice in establishing a definitive airway in the polytrauma setting. During direct laryngoscopy, significant movement occurs at the occipito-atlanto-axial joint. Manual in-line stabilisation (MILS) is used to minimise this movement. Previous anecdotal reports of the spinal cord being damaged following direct laryngoscopy in patients with unstable cervical spine injuries were based on weak coincidental evidence.[6] Therefore the technique of direct laryngoscopy with MILS is now an accepted safe technique for managing the airway in patients with potential cervical spine injuries. In addition the gum elastic bougie is a useful adjunct during direct laryngoscopy. It allows the anaesthetist to accept inferior views of the vocal cords thereby limiting the forces transmitted to the cervical spine and therefore movement. No particular laryngoscope blade has shown a superior benefit except the McCoy levering laryngoscope which will improve the view at laryngoscopy by up to 50% in simulated cervical spinal injuries. The McCoy is

therefore an alternative to the Macintosh for those experienced in its use (Figure 4).

The laryngeal mask airway (LMA) or intubating laryngeal mask airway are both extremely useful in the failed or difficult intubation. The forces applied during insertion can cause posterior displacement of the cervical spine but the movement is less than that seen in direct laryngoscopy. In the 'can't intubate, can't ventilate' scenario there should be early consideration of the surgical airway or cricothyroidotomy. These techniques can produce posterior displacement of the cervical spine but this should not prevent the use of this life-saving procedure.

Nasal intubation has formerly been included in the Advanced Trauma Life Support course airway algorithm. However, the low success rate and high incidence of epistaxis and layngospasm has resulted in this technique been superseded. Awake fibreoptic intubation has consistently produced the least amount of movement of the cervical spine in comparative studies. However in the acute trauma setting, blood or vomit in the airway may make the technique impossible. Further disadvantages include a relatively prolonged time to intubation,
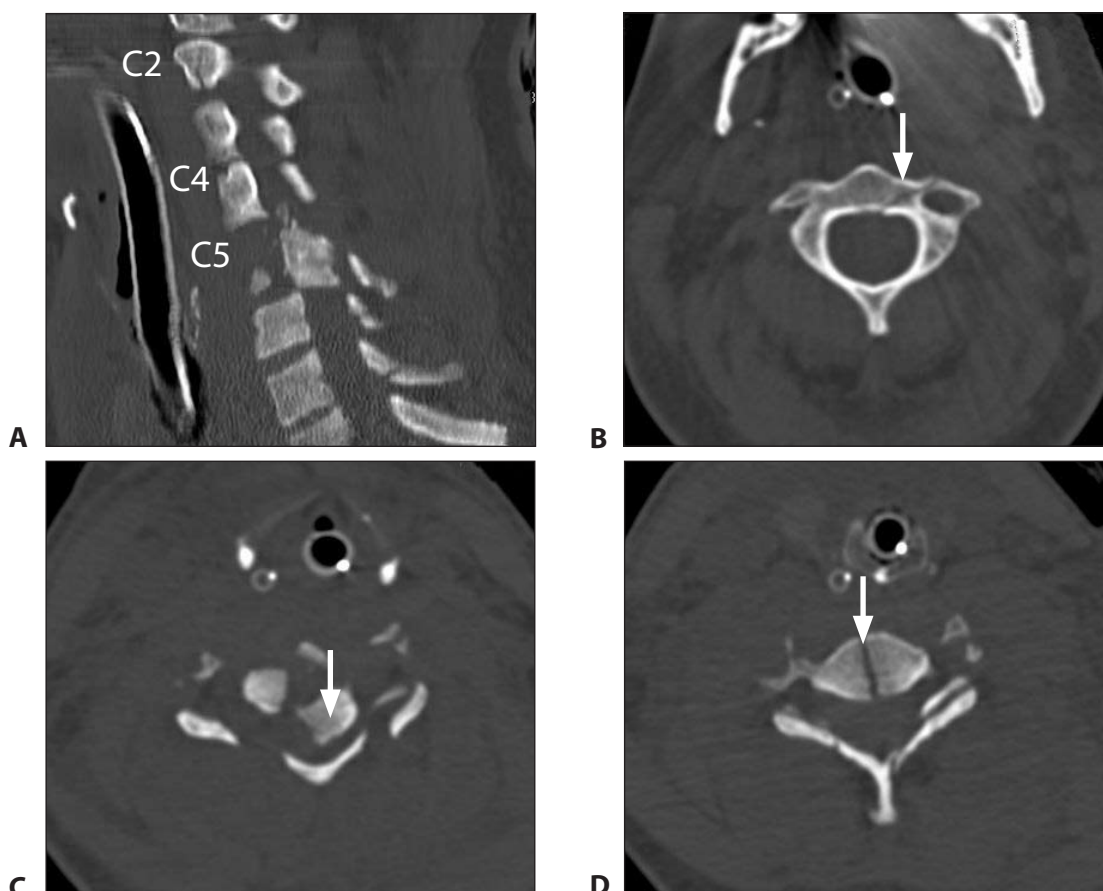

Figure 3. *Computed Tomography (CT) of the cervical spine. (A) sagittal reconstruction showing fractures at multiple levels; (B) transverse section fracture through the vertebral body of C2 to the left of the dens (arrowed); (C) transverse section - comminuted fracture with displacement of the left hemi-body of C5 into the spinal canal (arrow), presumably compressing the cord; (D) transverse section - midline fracture through the vertebral body of C6 (arrow), with bilateral fractures of the laminae of the vertebral arch*

risk of aspiration and, if gagging or coughing occur, an increase in the intracranial pressure (ICP). Despite theses concerns, for those anaesthetists with sufficient expertise and in the appropriately chosen patient, awake fibreoptic intubation is an option.[1,4]

Suxamethonium is safe to use in the first 72 hours and after 9 months following the injury. In the intervening period there is a risk of suxamethonium-induced hyperkalaemia due to denervation hypersensitivity and therefore should be avoided.

Spinal cord injury results in important pathophysiological consequences in various systems of the body that require appropriate treatment.

RESPIRATORY MANAGEMENT

Respiratory failure is common and pulmonary complications are the leading cause of death. The diaphragm (C3-C5) and intercostals (T1-T11) are the main inspiratory muscles. The accessory inspiratory muscles consist of sternocleidomastoid, trapezius (both 11th cranial nerve), and the scalene muscles (C3-C8). Expiration is a passive process but forced expiration requires the abdominal musculature (T6-T12). The abdominal muscles are therefore important for coughing and clearing respiratory secretions.

The severity of respiratory failure depends on the level and completeness of the injury. Complete dissection of the spinal cord above C3 will cause apnoea and death unless the patient receives immediate ventilatory support. For lesions between C3 to C5 the degree of respiratory failure is variable and the vital capacity can be reduced to 15% of normal. These patients are at risk of increasing diaphragmatic fatigue due to slowly progressive ascending injury resulting from cord oedema. This commonly results in retention of secretions and decompensation around day 4 post-injury, and intubation and ventilation is required. Where facilities are available some would electively intubate and ventilate patients in this group.

Initially the intercostal muscles are flaccid, allowing in-drawing of the chest during inspiration with a consequential compromise in respiratory

Figure 4. *The McCoy levering laryngoscope*

function. This gives the characteristic appearance of 'paradoxical breathing' – on inspiration the diaphragm moves down, pushing the abdominal wall out and drawing the chest wall inwards. As the muscles become spastic, respiratory function improves, allowing potential weaning of the patient from the ventilator. It is important to remember that paralysis of the abdominal musculature means that in the upright position the diaphragm works in a lower and less effective position and so a supine position is preferred. Abdominal binders are an alterative. Patients with high cervical spine lesions have increased bronchial secretions, possibly due to altered neuronal control of mucous glands.

In general, the decision to intubate depends on several factors, including:[7,8]

- loss of innervation of the diaphragm,
- fatigue of innervated muscles of respiration,
- failure to clear secretions,
- history of aspiration,
- presence of other injuries e.g. head and chest injuries,
- premorbid conditions, especially respiratory disease.

CARDIOVASCULAR MANAGEMENT

Cardiovascular instability is particularly seen with high cervical cord injuries. At the time of injury there is an initial brief period of increased sympathetic activity resulting in hypertension, an increased risk of subendocardial infarction and arrhythmias. This is followed by a more sustained period of neurogenic shock, resulting from loss of sympathetic outflow from the spinal cord, which may last up to eight weeks. This is characterised by vasodilatation and bradycardia and tends to be seen only in lesions above T6. Bradycardia is caused by loss of cardiac sympathetic afferents and unopposed vagal activity and may lead to asystole. This can be treated with atropine.

Hypotension is due to the loss of peripheral vasoconstriction. The loss of sympathetic innervation to the heart means that increases in cardiac output are primarily achieved by increases in stroke volume. The initial treatment of hypotension involves intravenous fluid administration. Once preload responsiveness is lost, (i.e. the stroke volume cannot be increased further), then vasopressors will need to be commenced using either dopamine or norepinephrine, which are both α- and β_2-receptor agonists, thereby providing vasoconstriction, chronotropic and inotropic support to the heart.[7, 8]

The end-point of resuscitation is controversial. There is evidence that ongoing ischaemia and secondary spinal cord damage is successfully treated by raising the mean arterial pressure to 85mmHg for up to seven days.[9]

AUTONOMIC DYSREFLEXIA

This complication does not occur during the acute phase of spinal injury but is mentioned here for completeness. The condition can be triggered by various stimuli including surgery, bladder distension, bowel distension and cutaneous stimuli. Severe signs are seen with higher lesions, and it is rarely seen in patients with cord lesions below T10. The symptoms may start weeks to years following the spinal injury and include paroxysmal hypertension, headaches and bradycardia. Below the lesion cutaneous vasoconstriction, piloerection and bladder spasm may be seen. Above the lesion there may be flushing, sweating, nasal congestion and conjunctival congestion. The patient may complain of blurred vision and nausea.

If left untreated, complications include stroke, encephalopathy, seizures, myocardial infarction, arrhythmias and death. Management options include removal and avoidance of triggers such as the insertion of a urinary catheter. If surgery is planned, consider the use of spinal anaesthesia as this reliably prevents the symptom complex. Other options include increased depth of anaesthesia and vasodilators for the treatment of hypertension.[8]

VENOUS THROMBOSIS

The incidence is 40 to 100% in untreated patients with a spinal injury and pulmonary embolism is one of the leading causes of death in this group of patients. Prophylaxis must be started as soon as possible although there is no consensus as to exactly when or how this should be initiated. Treatment can be divided into two clear groups, pharmacological and non-pharmacological. Low-molecular-weight heparin is effective in preventing deep vein thrombosis (DVT), but is associated with an increased risk of haemorrhage within the injured spinal cord if given acutely. Therefore mechanical compression devices and graduated elastic stockings are often applied for the first 72 hours when the risk of DVT is low and anticoagulants considered thereafter. Prophylaxis should be continued for at least eight weeks.[7]

GASTROINTESTINAL MANAGEMENT

Bleeding due to stress ulceration should be prevented with an H_2 receptor antagonist such as ranitidine. Ileus and gastric distention can be treated with nasogastric suctioning and prokinetic drugs, e.g. metoclopramide or erythromycin.[8]

SPECIFIC TREATMENT

Different therapies have been tried, attempting to reduce the secondary neuronal injury due to cord ischaemia and inflammation. Although some have shown potential in animal studies most have not shown significant benefit in clinical studies. Only methylprednislone has shown any promise.

There have been four randomised, controlled trials involving high dose methylprednisolone. The most discussed are the three National Acute Spinal Injury Studies (NASCIS), showing that administration of methylprednisolone in the acute phase showed a slight but significant benefit. However, this was at the cost of increases in the incidence of pneumonia and sepsis and the trials were criticised on several levels. Therefore methylprednislone is only a treatment option and cannot be considered a standard of care.

Early surgical decompression has been shown to be benefit in animal models of spinal cord injury. To date the evidence in humans is lacking, and the timing of surgical decompression remains a topic of debate and ongoing research.[10]

SUMMARY

The initial management of patients involved in blunt trauma follows the ATLS principle of airway and cervical spine control, breathing and circulation. The spine is immobilised as soon as possible to prevent secondary neurological injury. However, extrication collars should be removed and MILS applied prior to establishing a definitive airway, where this is indicated. Despite movement at the occipito-atlanto-axial joint, direct laryngoscopy with MILS is an accepted safe method to manage the airway in patients with potential cervical spine injuries. The gum elastic bougie and the McCoy laryngoscope are useful tools in this context. A cervical spine injury is likely to result in respiratory failure and cardiovascular instability, which may require ventilatory and/or inotropic support.

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Anaesthesia for foot and ankle surgery - general and regional techniques

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Summary

Regional and general techniques to provide anaesthesia and postoperative analgesia for foot and ankle surgery are discussed. Spinal anaesthesia is appropriate for shorter procedures, whereas general anaesthesia in combination with a regional technique is generally used for procedures over two hours. Ankle block and sciatic nerve block at the knee provide effective perioperative analgesia and both are described in detail.

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INTRODUCTION

Anaesthesia for foot and ankle surgery can be provided by general or loco-regional anaesthesia and, given the peripheral site of surgery, a combination of both is generally well-tolerated. Regional anaesthesia confers excellent analgesia postoperatively, reducing the requirements for systemic analgesics. Anaesthetic techniques are usefully divided into those appropriate for surgery to the foot and those for surgery to the ankle.

If you are unsure about your choice of an appropriate regional technique, talk to the surgeon to clarify the site of surgery and incision, and the anticipated postoperative pain.

ANATOMY

The sensory supply to the foot and ankle is shared between branches of the femoral and sciatic nerves. The motor supply is almost exclusively from the posterior tibial nerve (a branch of the sciatic nerve).

Femoral nerve (L2-4)

The terminal branches form the saphenous nerve (L3-4), which supplies the skin over the medial malleolus, the medial aspect of the foot, with variable innervation to the head of the first metatarsal.

Sciatic nerve (L4-S3)

The sciatic nerve divides into the tibial and common peroneal nerves at a variable level between the buttock and popliteal fossa. Commonly this is about 6-10 cm proximal to the posterior knee skin crease, but may occur more proximally in up to 30% of patients.

The tibial nerve supplies motor nerves to the flexor muscles of the calf and foot, and divides into the posterior tibial and sural nerves. The posterior tibial nerve passes posteriorly to the medial malleolus, running just posterior to the tibial artery. It then divides into the medial and lateral plantar nerves in the foot, which supply motor innervation to the foot and sensory nerves to the internal structures of the foot and skin over the sole of the foot. The sural nerve supplies sensation to the lateral aspect of the heel and foot, with the calcaneal branch of the tibial nerve supplying the remaining parts of the heel.

The common peroneal nerve winds around the head of the fibula and then divides into

Table 1. *Foot and ankle surgery*

Site of surgery	Examples	Anaesthesic technique
Foot (i.e. midfoot, forefoot and toes)	• Scarf osteotomy (bunionectomy) • Weil osteotomy • Calcaneal fracture repair	General with **ankle block** or Spinal if surgery less than 1½ - 2 hours
Ankle	• Ankle arthroscopy • Arthrodesis (e.g. tibio-talar fusion) • Ankle replacement	General with more proximal block (e.g. **popliteal block**) or Spinal if surgery less than 1½ - 2 hours

superficial and deep branches, supplying the dorsum of the foot and ankle, and the first web space respectively.

ANAESTHESIA FOR FOOT SURGERY
General points
- General anaesthesia (GA) with an ankle block, or spinal anaesthesia is usually appropriate. Where patient choice or medical co-morbidities dictate, spinal anaesthesia may be used for procedures lasting less than 1½ to
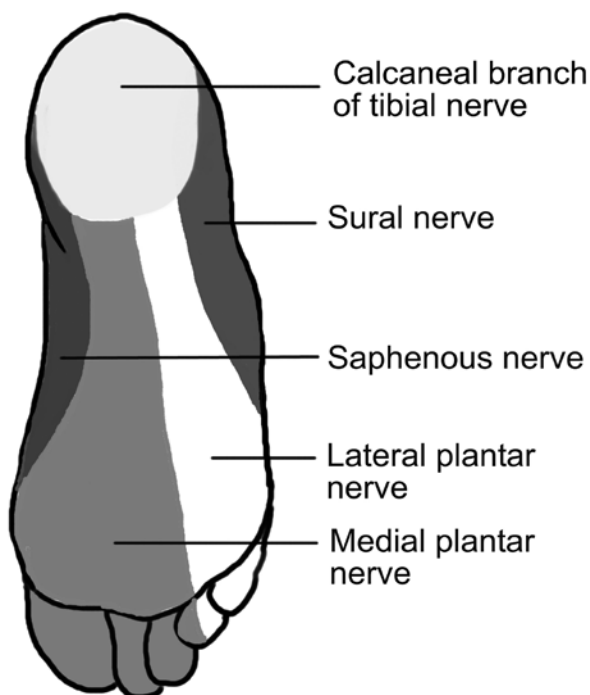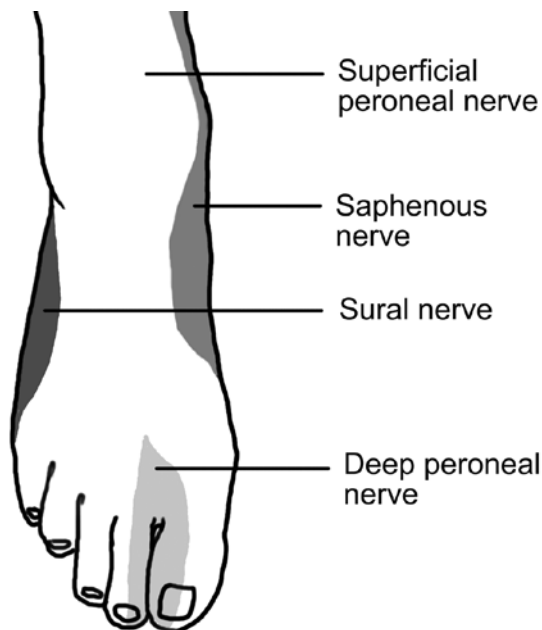
Figures 1 and 2. *Sensory innervation of the foot and ankle*

2 hours. Ankle block is usually combined with general anaesthesia, but may be used as the sole anaesthetic in patients who are unfit for GA. Be aware that the onset time is usually in excess of 30–40 minutes and that performing the block is painful and some form of sedation is recommended.

- Longer-acting local anaesthetic agents are preferred and generally provide analgesia for 12 hours or greater.

- The maximal safe dose for bupivacaine is 2mg.kg^{-1}. Where only lignocaine is available 3mg.kg^{-1} can be used; this can be increased to 7mg.kg^{-1} if epinephrine is added, but this is not advisable for ankle block due to the risk of causing ischaemia of the foot. Analgesia may be prolonged by the addition of clonidine to the local anaesthetic.

- Where available local anaesthetic catheters may be placed for longer term use in the postoperative period.

- Check the block prior to surgery, testing sensation to pinprick.

- If anaesthesia is inadequate, identify which nerve supplies the relevant area and repeat the infiltration of that nerve.

- Within the limits of maximal local anaesthetic doses, advise the surgeon to infiltrate locally during surgery to augment the block.

ANKLE BLOCK
Preparation
1. Check resuscitation equipment and drugs.

2. Perform block in an anaesthetic or operating room.

3. Explain procedure to patient and obtain consent.

4. Establish IV access.

5. Full monitoring is advised where available (ECG, pulse oximetry, NIBP).

Technique - general
- Performing the block is painful so remember to inject the local anaesthetic (LA) slowly. Heating the local anaesthetic to body temperature may also help to reduce pain. Sedation is usually required.

- All five nerves can be blocked with the patient supine and the foot on a padded support. Some prefer to block the **posterior tibial** and **sural nerves** with the patient prone. To block the posterior tibial nerve in a supine position, externally rotate the leg, with the

knee slightly flexed – this allows the foot to be externally rotated.

- When a nerve stimulator is not available, a 23G needle, 3-4cm in length is appropriate for all injections. It is important always to aspirate prior to injection of local anaesthetic, to exclude intravascular injection.

- The authors feel that more use of a higher concentration of local anaesthetic (e.g. 0.5% bupivacaine) improves the success of the block.

- Most foot and ankle procedures require block of the **posterior tibial** nerve, since it also provides sensory innervation to most of the internal tissues of the foot. However, it is not always essential to block all four of the remaining nerves and your choice of injections should be tailored to suit the surgical procedure. If in doubt, ask the surgeon where his incisions will be and aim to cover these areas.

- Optimise analgesia with paracetamol and, where appropriate, a non steroidal antiinflammatory agent.

- Most surgeons use a thigh or calf tourniquet for these procedures and so additional intraoperative analgesia is often required to cover this. Tourniquet pressure is usually 100mmHg above the systolic blood pressure (generally 250mmHg is chosen). The risk of ischaemic damage is reduced if the tourniquet time is limited to 2 hours. The physiological response to tourniquet pain may make it difficult to assess whether the block is working and it is unwise to wake a patient relying totally on a block to provide effective analgesia.

- Most patients are positioned supine, with a wedge under the buttock on the operative side.
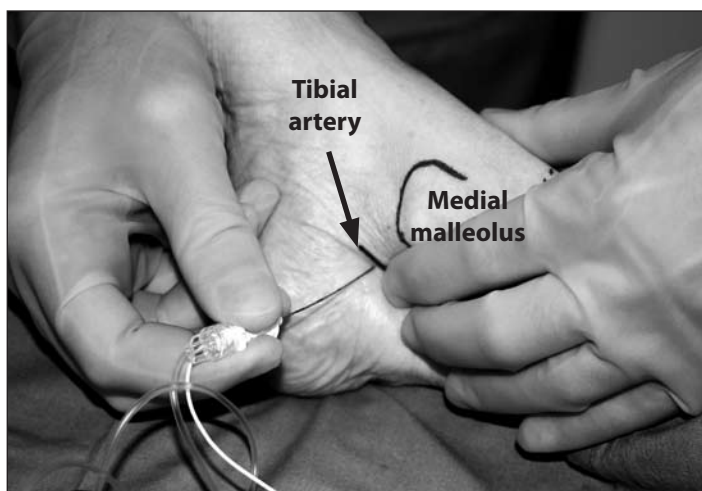
Technique – specific nerve blocks

Always aspirate to exclude for vascular puncture before injecting local anaesthetic.

Posterior tibial nerve (this nerve can be located with a nerve stimulator – see below)

- Palpate the tibial artery just posterior and inferior to the medial malleolous. Insert the needle to pass 2-3 mm posterior to the artery (Figure 3).

- If paraesthesia is felt, inject 3-5ml LA. If not, advance to contact the tibia, withdraw 0.5cm and then inject 7-8ml LA.

Use of a peripheral nerve stimulator to locate the posterior tibial nerve.

- Of the five nerves supplying the operative field, only the **posterior tibial nerve** has a major motor supply. Where available, use of a peripheral nerve stimulator to locate this nerve behind the medial malleolus improves the success of the block (see Figure 3).

- Using a 50mm stimulator needle, look for flexion of the great toe or, less commonly, flexion of the other toes (Figure 4).

- Be aware that the threshold current for stimulation is usually higher than that achieved for other nerves and a higher value should be accepted. In practice any sort of stimulation indicates that the needle tip is close to the nerve, but it is worthwhile checking that the threshold is above 0.3mA (implying that the needle tip is not within the nerve). Be aware that conditions causing peripheral neuropathy (e.g. diabetes) may cause an abnormal or absent response to nerve stimulation.
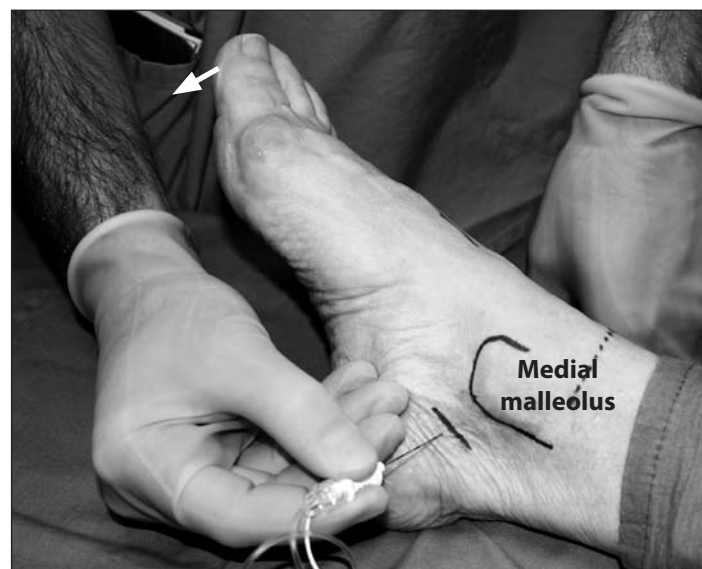

Figure 3. *The posterior tibial nerve is located immediately posterior to the tibial artery behind the medial malleolous*

Figure 4. *Successful location of the posterior tibial nerve is indicated by flexion of the hallux (arrow)*

Figure 5. *(A) Needle insertion point for block of superficial peroneal nerve laterally (B) and saphenous nerve medially (C)*
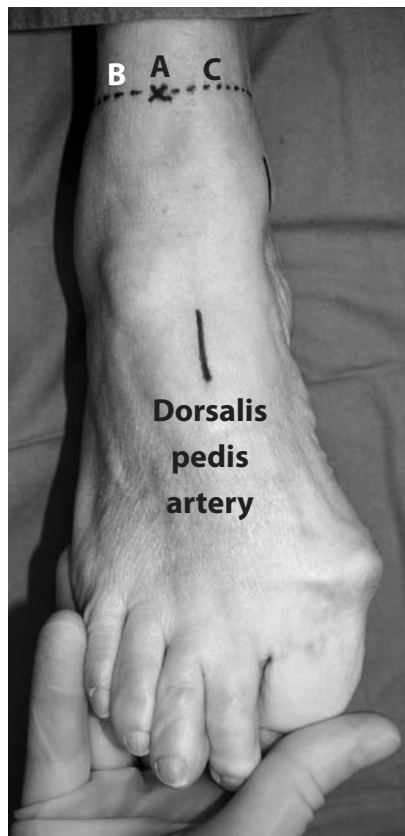

Figure 6. *Block of the saphenous nerve by infiltration in a band between the needle entry point and the superior border of the medial malleolus (shown by dotted line)*

- Use of a peripheral nerve stimulator reduces the volume of local anaesthetic agent required (usually 5ml for the posterior tibial nerve) and, in the authors' opinion, improves the success rate of the block (although some authors estimate the success rate at 90% without use of nerve stimulation). Block failure is overcome by supplementation with local infiltration provided by the surgeon.

Sural nerve
- Introduce the needle along the lateral border of the Achilles tendon at the level of the cephalic border of the lateral malleolus.

- Advance anteriorly towards the fibula.

- If parasthesia is felt inject 3-5ml LA. If not, inject 5-7ml LA as the needle is withdrawn. This gives subcutaneous infiltration from the Achilles tendon to the fibula.

Superficial peroneal nerve
- Infiltration around the superficial peroneal and saphenous nerves can be performed from a single site. The needle is inserted subcutaneously at the most anterior point of the lower leg at the level of the cephalic borders of the malleoli (Figure 5).

- Turn the needle towards the lateral malleolus and inject 3ml LA in a subcutaneous band between the lateral malleolus and the anterior border of the tibia

(Figure 5). This should reach all the branches of this nerve.

Saphenous nerve
- Withdraw the needle to just stay in the skin and turn the needle to point towards the medial malleolus (Figures 5 and 6).

- Infiltrate 3ml LA subcutaneously as the needle is advanced towards the medial malleolus (Figure 6). The great saphenous vein lies in this area, just antero-medial to the medial malleolus - in order to infiltrate around the vein without causing damage, it may be necessary to make a further skin puncture lateral to the vein.

Deep peroneal nerve
- Palpate the dorsalis pedis (anterior tibial) artery. Insert your needle superficial to the artery and pass it posteriorly to the left and then right of the artery, injecting 2ml LA deep to the fascia on each side (Figure 7).

- If the artery cannot be felt, insert the needle between the tendons of extensor hallucis longis (medially) and extensor digitorum (laterally), about one third of the way down the foot from the ankle to the toes. The extensor hallucis longis tendon is prominent on the dorsum of the foot during extension of the big toe.

Figure 7. *Block of the deep peroneal nerve using injections on either side of the dorsalis pedis artery*

Cautions

1. It is best to avoid adrenaline in the LA. There are theoretical risks to the foot from the vasoconstrictor effect.

2. Although systemic absorption from the subcutaneous tissues of the ankle is low, and toxicity is therefore unlikely, total recommended maximum total dose of local anaesthetic should not be exceeded.

Notes for specific surgical procedures

Scarf osteotomy

• Realignment osteotomy of the first metatarsal ('bunionectomy').

• Postoperative pain is considerable.

• The surgeon makes an incision along the medial aspect of the first matetarso-phalangeal joint (posterior tibial nerve, saphenous nerve and superficial peroneal nerve). Some surgeons make a second incision in the first web space (deep peroneal nerve) to release the sesamoid bones from the lateral ligaments. The sural nerve does not need be blocked.

Weil osteotomy

• Correction of claw toe with osteotomy of the metatarsal – often multiple.

• Block the same four nerves as above and, if the fourth and fifth metacarpal bones are involved, then a sural nerve block should also be performed.

• Injection of local anaesthetic into the webspaces disrupts the surgical field and should be avoided.

Metatarso-phalangeal fusion

• Usually the first metatarsal, for severe hallux valgus or pain due to osteoarthritis.

• Depends on the joints involved. Generally will require posterior tibial, saphenous, superficial and deep peroneal blocks. Sural block should be added if the 5th digit is involved.

Zadecks procedure

• Partial nail-bed excision.

• A simple ring block of the digit can be used. Vasoconstrictors should be avoided.

Excision of Morton's neuroma

• A neuroma in the webspace of the toe – often multiple.

• Although an ankle block will cover the incision(s), infiltration of local anaesthetic by the surgeon will be sufficient. Web space blocks by the anaesthetist are inappropriate since they disrupt the surgical field.

Note that for revision surgery, some surgeons prefer to make an incision in the sole of the foot – this painful approach would benefit from an ankle block.

ANAESTHESIA FOR ANKLE SURGERY

An ankle block is unlikely to provide complete analgesia for more proximal surgery. In addition, injection sites for an ankle block are likely to be at the site of surgical incision. If unsure whether to use an ankle or more proximal block, discuss the choice with the surgeon. Techniques to anaesthetise the femoral and sciatic nerves more proximally are appropriate (see Nerve blocks for anaesthesia and analgesia of the lower limb in *Update 11*, 2000, available at www.worldanaesthesia. org), however much of the motor weakness caused by a proximal sciatic nerve block can be avoided by blocking the tibial and common peroneal nerves in the popliteal fossa. This is a useful alternative for ankle (and some more proximal midfoot) surgery. These nerves can be blocked using a lateral or posterior approach. If surgery includes the medial side of the ankle, the saphenous nerve can be blocked just below the knee (see below).

SCIATIC NERVE BLOCK AT THE POPLITEAL FOSSA

Popliteal Nerve Block - Lateral approach

Indications

• Ankle and foot surgery.

• Provides anaesthesia for a calf tourniquet.

Anatomy

• The sciatic nerve lies lateral to the popliteal artery and vein (see Figure 8) and divides into the tibial and common peroneal nerves between 6 and 10cm above the politeal crease. In 70% of individuals, this division occurs within 10cm of the popliteal crease.

Preparation

As for ankle block.

Technique

- This technique requires use of a peripheral nerve stimulator and an appropriate (usually 100mm) short bevelled needle.

- The patient is positioned supine with the leg straight and the whole leg and foot exposed. The patient is usually mildly sedated.

- The groove between vastus lateralis and biceps femoris is palpated and a position in this groove, 8 cm proximal to the popliteal crease in identified (see Figure 9). The landmarks can be accentuated by asking the patient to perform a straight leg raise. After injecting a small amount of local anaesthetic subcutaneously, insert a 100mm stimulating needle in a horizontal plane, between your two fingers pressed into the groove. Aim to hit the femur within 2-3cm of the skin

Tibial nerve	Common peroneal nerve
Plantar flexion of ankle or toes	Dorsiflexion of ankle or toes
Inversion of foot	Eversion of foot

('A' in Figure 8 and Figure 10). When you have identified the femur, withdraw the needle to the skin and redirect 30 to 45° posteriorly (towards the bed) – 'B' in Figure 8 and Figure 11. Advance slowly towards the sciatic nerve stimulating with a current of 1.5mA. Look for movement of the foot or toes:

- The depth of the nerve is usually 5-7cm. Stimulation of the common peroneal nerve is usually encountered first, since it lies more laterally. Stimulation of either nerve is acceptable, since injection of a large volume of local anaesthetic should be sufficient to block both nerves, which lie in close proximity at this level. Aim to achieve a threshold for stimulation of 0.3 to 0.5mA. Inject 30-35ml local anaesthetic (e.g. 0.375% bupivacaine).

- Do not accept isolated twitches of the calf muscle.

- If no stimulation is achieved, first check all of your electrical connections. Then withdraw the needle and reinsert aiming a further 5-10° posteriorly. If this is still unsuccessful, repeat the process, realigning a further 5-10° posteriorly. Do not re-align anteriorly, since there is a high risk of hitting the popliteal artery or vein (see Figure 8).
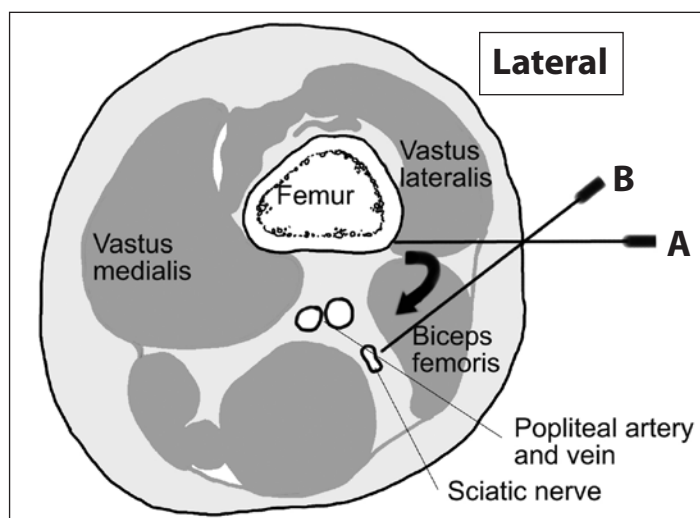

Figure 8. *Cross-section through the left thigh 8cm above the popliteal crease, showing relative positions of the sciatic nerve and the popliteal artery and vein*

- Remember that the skin over the medial malleolus is not covered by this block and is innervated by the saphenous nerve which can be blocked separately by a fan of local anaesthetic anterior and proximal to the medial malleolus (as described above) or at the knee (see below).

Figure 9. *Palpation of the groove between vastus lateralis and biceps femoris*

Figure 10. *Needle insertion in a horizontal plane to hit the femur*
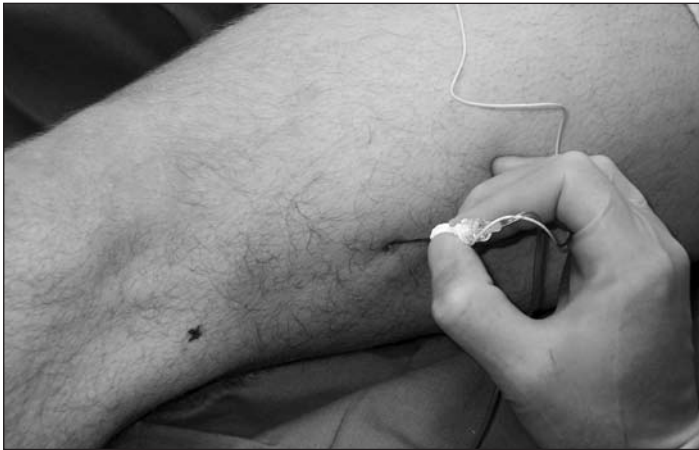
Figure 11. *The needle is withdrawn to the skin and then advanced at an angle of 30-45° posteriorly (towards the bed) until calf or foot movement is seen*

Potential complications
These should be discussed with the patient prior to attempting the block and include: vascular puncture, haematoma, nerve injury and failure of block.

Popliteal Nerve Block – Posterior approach
Anatomy
The popliteal fossa is bordered by the biceps femoris laterally, and by semimembranosis and semitendonosus medially, forming a triangle. The base of the triangle is formed by the popliteal crease. The sciatic nerve lies lateral to the popliteal artery and vein, dividing into the tibial and common peroneal nerves.

Technique
- The block can be performed with the patient in the prone position or supine, with the hip and knee flexed.
- With patient supine, the hip and knee are flexed to 90°, asking an assistant to support the lower leg.
- The borders and apex of the fossa are identified. A point is identified, 6-8 cm proximal to the popliteal
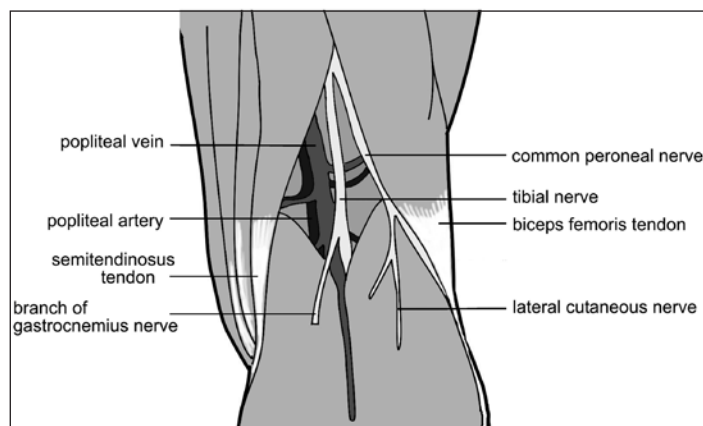

Figure 12. *The anatomy of the popliteal fossa (posterior aspect).*

crease, and 1 cm lateral to the midline. (The apex of the triangle is in the midline).
- Using a 50mm stimulator needle, the same end-point is sought as with the lateral approach.
- The same volume of local anaesthetic agent is used.

Complications
As for lateral approach.

SAPHENOUS NERVE BLOCK AT THE KNEE
The saphenous nerve should be blocked for all surgery involving the medial ankle. A 25G needle is inserted 2cm medial to the tibial tuberosity. A fan of local anaesthetic agent (8-10ml) is infiltrated from this site to the posterior part of the medial tibial condyle.

Notes for specific surgical procedures
Ankle/lower tibial fractures
- Neurovascular compromise for fractures involving the ankle may necessitate emergency surgery. Ensure that if the patient is insufficiently starved, you take appropriate measures during induction and emergence from general anaesthesia.
- Ask the surgeon if compartment syndrome is a risk, since more proximal blocks of the sciatic nerve may mask symptoms and should therefore be avoided.

Ankle arthroscopy – diagnostic
- Intra-articular LA injection by surgeon is sufficient.

Ankle arthroscopy – interventional (may be done as an open procedure)
- Postoperative pain is significant and popliteal block is recommended.

SUMMARY
Surgery to the foot and ankle can produce extreme intraoperative stimulation and severe postoperative pain. Use of general anaesthesia, combined with an appropriate regional technique, guided by knowledge of the surgical technique and the nerve supply of the operative area, will facilitate a smooth perioperative course and good postoperative analgesia. Spinal anaesthesia is appropriate for shorter cases.

ACKNOWLEDGEMENTS
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FURTHER READING
Morphett S. Nerve blocks for anaesthesia and analgesia of the lower limb. *Update in Anaesthesia* 2000; **11**: 56-66. Available at www.worldanaesthesia.org

Update in Anaesthesia

BRIEF COMMUNICATION

Anaesthesia training: where and how it is conducted in French-speaking sub-Saharan Africa?

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SUMMARY

This survey used a questionnaire to index the different training schools, evaluate the various courses available and to evaluate the impact on the numbers of anaesthetists in French-speaking sub-Saharan Africa. Six centres training physician anaesthetists (Bénin, Ivory Coast, Senegal, Cameroon, Rwanda and Democratic Republic of Congo - DRC) and 11 schools for nurse anaesthetists (Bénin, Burkina Faso, Ivory Coast, Cameroon, Gabon, Congo, Mali, Senegal, Togo, Rwanda and DRC) were identified. Whereas the entry requirements for the schools training doctors were similar, those for the nurse training schools were disparate and the impact of available training on the number of anaesthetists within a country was striking. Coordinating the different training programs, increasing the intake capacity of the different schools and facilitating movement of trainers across French-speaking Africa will hopefully promote improvements in both anaesthesia training and recruitment. This will require the support of national and international organisations.

INTRODUCTION

The progress seen in anaesthesia over the last few decades has largely occurred due to improved knowledge in pathophysiology and pharmacology, linked to an increase in the number of trained, qualified anaesthetists. With this growth, anaesthesia has become safer in developed countries with anaesthetic related deaths a low as 0.001% (1 in 100,000).[1] In contrast, in developing countries, anaesthesia still carries huge risks,[2] with a perioperative mortality rate in the range of 2.2 to 2.7%; ten times higher than in France in 1980 (0.2%).[3] There are many contributing causes for this situation in developing countries, but the impact of factors related to the numbers and training of staff is significant. Due partly to reforms in Europe and also the prohibitive cost of a prolonged period of training in Western countries, the training of anaesthetists in their home countries has become an urgent priority. Where and how do healthcare staff train in anaesthesia in French-speaking sub-Saharan Africa? What is the impact of these training schools on the numbers and distribution of anaesthetists in this region?

METHODOLOGY

This was a prospective questionnaire-based study, run over 4 months (Nov 2001 to Feb 2002) in the 17 French-speaking countries south of the Sahara: Bénin, Burkina Faso, Cameroon, Ivory Coast, Congo, Gabon, Guinea, Mali, Mauritania, Madagascar, Niger, Central African Republic, Democratic Republic of Congo, Rwanda, Senegal, Chad and Togo.

The data was collected by a questionnaire which was either sent to the heads of the training departments by email, or completed during a direct interview at the SARANF (Society of Anaesthesia of French-speaking Africa) Congress, held in Cotonou, Bénin in 2001. In Cotonou, Abidjan (Ivory Coast), Yaoundé (Cameroon), Lomé (Togo) and Libreville (Gabon) we made on-site enquiries in the different training centres. For each training programme we collected data on entry requirements, the course, the number of diplomas issued and the number of trained anaesthetists.

RESULTS

Training centres for physician anaesthetists

Six medical facilities train physician anaesthetists:

Physician Anaesthetists:
[1]Centre Hospitalier Universitaire de Lomé-Tokoin, Togo

[2]Hôpital Universitaire de la Mère et de l'Enfant Lagune (HOMEL), Bénin

[3]Hôpital Gynéco-Obstétrique et Pédiatrique de Yaoundé (HGOPY), Cameroon

[4]Centre Hospitalier Universitaire Pédiatrique Charles De Gaulle, Burkina Faso

[5]Institut Supérieur des Techniques Médicales, Democratic Republic of Congo (DRC)

[6]Kigali Health Institute, Rwanda

[7]Institut Cardiologique d'Abidjan, Ivory Coast

Dakar in Senegal, Abidjan in Ivory Coast, Cotonou in Bénin, Yaoundé in Cameroon, Kinshasa in DRC and Kigali in Rwanda (Table 1). The entry requirements for all 6 schools were identical; possession a medical degree from your country of origin and pass an entry test to the school of anaesthesia. However, the nature of the different training programmes themselves varied between schools. The training departments train doctors of a variety of nationalities. For example in Cotonou (Bénin) in 2007, there were 27 students of 7 different nationalities (5 Togolese, 4 from Burkina Faso, 2 Nigerians, 1 from Chad, 1 from Guinea, 1 from DRC and 13 from Bénin).

Training centres for nurse anaesthetists

There are 11 training centres: Burkina Faso, Mali, Senegal, Togo, Bénin, Cameroun, Central African Republic, Ivory Coast, Gabon, DRC and Rwanda. The class sizes for each intake and syllabus varied from one institution to another, as did the admission criteria. For example in Dakar and Lomé state registered nurses with 2 or 3 years experience are accepted for entry, as well as school leavers after their baccalaureat examination. There are reforms in place at the moment to try to incorporate the nurse anaesthetist training with the LMD (Licence Master Doctorat) system and to produce a uniform system across French-speaking Africa.

Impact on the numbers of practicing anaesthetists within each country

In 2008 the four countries in West Africa who train physician anaesthetists (Senegal, Ivory Coast, Bénin and Cameroon) have 105 doctors for a population of 52,963,000 - 1 physician anaesthetist for half a million population. This disparity is even greater in Central Africa where the two countries that train physician anaesthetists (Rwanda and DRC) have only 26 doctors for a population of 66,587,000 - 1 physician anaesthetist for 2.5 million population.

There are currently 956 nurse anaesthetists in the 7 West African countries with a training institution. With a total population of 87,464,000, this computes to one nurse anaesthetist for just less than 100,000 people. In the French-speaking Central African countries where there are training institutions there are 704 nurse anaesthetists for a population of 72,009,000 (Tables 1 and 2).

DISCUSSION

While the number of anaesthetists in countries with training institutions is low, it is potentially catastrophic in the other sub-Saharan French-speaking countries. For example, in Chad in 2007 there was one physician anaesthetist and 22 nurse anaesthetists for a population of 8,582,000. In Guinea Conakry there 3 physician anaesthetists and 40 nurse anaesthetists for a population of 7,909,000.[4] This dearth of qualified personnel is a prime contributing factor to the unacceptably high incidence of perioperative death. The numbers of qualified anaesthetists has gradually increased since 1999, especially in the countries with training institutions and this, along with the establishment of two new training schools in Bénin and Rwanda, has provided a starting point towards resolving this problem.

In addition to these significant improvements further changes are needed:
- Increasing the intake capacity of the different training institutions,
- Promoting high quality training facilitated by increasing conformity between the different courses,

Table 1. *Training of physician anaesthetists - characteristics of training schools since 2002 and numbers of physician anaesthetists in 2008*

Country	Date school opened	Number qualified since 2002	Length of training	Total number 2008 (practising anaesthetists)	Population ** (x 1000 inhabitants)
Bénin	1996	3	4 years	16	8439
Cameroun	1987	9	4 years	28	16322
Sénégal	1995	20	4 years	25	10048
Ivory Coast	1983	82	3 years*	36	18154
DRC	1968	4	4 years	17	57549
Rwanda	2002	-	4 years	9	9038
Total	-	118	-	131	119550

* The length of training has been extended to 4 years

** Source: http://www.afro.who.int/home/countryprofiles.html

Table 2. *Training of nurse anaesthetists - characteristics of training schools since 2002 and number of nurse anaesthetsists in 2008*

Country	Date school opened	Number qualified since 2002	Length of training	Total number in 2008 (practising nurse anaes-thetists	Population (x 1000 inhabitants)
Burkina-Faso	1983	96	2 years	116	13228
Cameroun	1994	95	2 years	170**	16322
Sénégal	-	100	2 years	112	11658
Ivory Coast	1972	199	2 years	232	18154
Togo	1989	74	3 years	89	6145
Mali	1991	47	2 years	57	13518
Bénin*	2002	-	3 years	180	8439
CAR	1995	36	2 years	46	4038
Gabon	1982	61	2 years	81	1384
Rwanda	1999	42	2 years	157***	9038
DRC	1970	350	3 years	420	57549
Total	-	1100	-	1660	159473

* Bénin now has 180 nurse anaesthetists of which 63 were trained in-country since the school opened in 2002-2003. The majority of the remainder were trained in Togo and Ivory Coast.

 ** 25 trained 'on the job'.

*** Only 3 didn't have their training in-country.

- Encouraging the movement of trainers across the region, which will be enhanced by the coordination of national policies in the training of anaesthetists.

Health ministries have an essential role in ensuring these changes occur, particularly for the latter point. It is our duty to draw the readers' attention to the appalling maternal mortality rates in developing countries, to which anaesthesia contributes.[6] In the future we will need as many qualified anaesthetists as obstetricians.

Politicians must devise a focused plan that promotes the integration and development of professional physician anaesthetists, which will prevent their emigration to other countries where they may be treated as second class practitioners.

ACKNOWLEDGMENT

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BRIEF COMMUNICATION

Audit of waiting time to theatre for non-obstetric emergency and urgent cases in Livingstone General Hospital, Zambia

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INTRODUCTION

In 1985 the UK Confidential Enquiry into Perioperative Deaths (CEPOD) published a set of definitions to help describe the urgency of surgical procedures (Table 1).[1]

Table 1. *The NCEPOD classification of surgical procedures*[1]

Emergency

Immediate life-saving operation, resuscitation, simultaneous with surgical treatment (e.g. trauma, ruptured aortic aneurysm).

Operation usually within one hour.

Urgent

Operation as soon as possible after resuscitation (e.g. irreducible hernia, intussusception, oesophageal atresia, intestinal obstruction, major fractures).

Operation within 24 hours.

Scheduled

An early operation but not immediately life-saving (e.g. malignancy).

Operation usually within three weeks.

Elective

Operation at a time to suit both the patient and surgeon (e.g. cholecystectomy, joint replacement).

Livingstone General Hospital is a 300-bed secondary level hospital in Zambia. Long waiting times for surgery in urgent and emergency cases were perceived to be major problem in the hospital, but there was no documented evidence for this. An audit was conducted over a 12-month period to gather data on the waiting time for surgery for cases fulfilling the NCEPOD classification for urgent or emergency operation. The aim of the audit was to identify potential areas for improvement in the theatre service and provision of patient care.

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MATERIALS AND METHODS

A retrospective audit was performed of all non-obstetric urgent and emergency surgical cases at Livingstone General Hospital from March 2006 to February 2007. Using the patients' notes and the theatre operating book, data detailed age, sex, admitting medical specialty and diagnosis, date and time of admission, surgical diagnosis and operation performed. Outcome data were not collected. Cases were classified as urgent or emergency according to their surgical diagnosis. Waiting time was defined as the time from admission to hospital to the time of transfer to theatre. For urgent cases where the waiting time to theatre could not be determined precisely (ie. to the nearest hour), the time to theatre was estimated, rounded down to the nearest whole day.

RESULTS

Incomplete or missing records were a major problem; only 42 out of a potential 78 cases provided sufficient data for analysis.

Of the 42 cases included in the audit the mean age was 28 years (range 3 – 75 years) and 70.5% were male. The most common diagnoses were intestinal obstruction (18%) and stab injury to the chest or abdomen (18%).
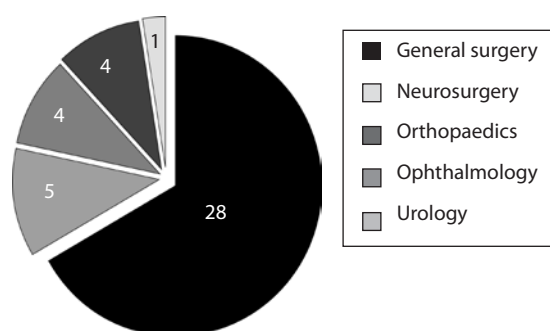

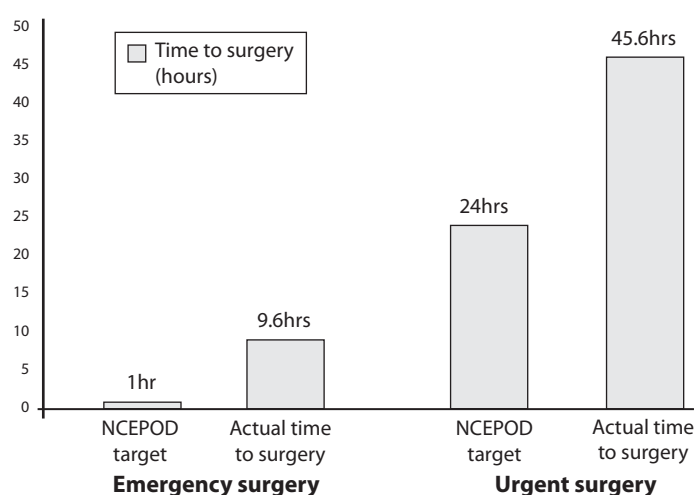**Figure 1.** *Breakdown of specialties of the 42 cases included in the audit*

Figure 2. *Median waiting time to theatre for patients requiring emergency and urgent surgery*

The median waiting time for all cases was 1.3 days. Median waiting time for emergency surgery was 9.6 hours (range 1.8 - 17.8 hours) and for urgent cases was 1.9 days (46.6 hours) (range 6 hours - 38 days).

Of the 36 urgent cases, 15 (42%) had their surgery within the 24 hour target. The shortest waiting for urgent surgery was 6 hours (intestinal perforation), while the longest was 38 days (also intestinal obstruction).

Of the 6 emergency cases, none achieved the NCEPOD recommended waiting time for emergency surgery. The shortest time to surgery was 1.5 hours for three cases that were all stab wounds to the chest or abdomen. The longest wait for emergency surgery was 17.8 hours, also a stab wound.

Of note, five out of six patients with a diagnosis of simple appendicitis were subsequently found at operation to have a perforated appendix. These five patients had waiting times from admission to surgery of 6.5 hours, 24 hours, 24 hours, 40 hours and 31 days. There was only one patient with acute appendicitis who did not perforate; this patient waited 48 hours for surgery. Other cases of note are detailed in table 2.

DISCUSSION

While accepting that the data collection was incomplete, this audit shows that patients booked for both urgent and emergency surgery at Livingstone General Hospital can expect

Table 2. *Cases where surgery was delayed*

Cases	Delay	Comments
11 year old female	31 days	Found to have a perforated appendix
37 year old male	30 days	Penetrating eye injury
31 year old male	18 days	Fractured femur
3 cases of intestinal obstruction	30 days	

a long delay before their surgery is performed. A minority of patients met the target waiting times set by the NCEPOD recommendations. The median waiting time for emergency cases exceeded the NCEPOD target by over ninefold and in the urgent group by almost twofold. The audit took no account of the time from onset of symptoms to the time to presentation at the hospital, but it is likely that this is significant for this poor rural community. Although outcome data was not collected, it is unlikely that prolonged waiting times for surgery after admission to hospital were of benefit to the patients. This is highlighted by the high proportion of patients with appendicitis who were found to have a perforation at laparotomy.

The poor quality of note-keeping hampered accurate estimation of times to surgery, and it was for this reason that time to surgery was estimated using the time from admission to hospital to arrival in theatre. Some patients may have had a delayed diagnosis and others, for example those with bowel obstruction, may have undergone a trial of non-surgical treatment prior to being listed for surgery. Reassuringly, only three patients of 42 had evidence that the surgical diagnosis was delayed after admission; these were three cases of intestinal obstruction where diagnosis was delayed by 14 hours, 4 days and 11 days respectively. Once the diagnosis had been made, each case only waited a further 1 hour 20 min, 5 hours and 5 hours respectively for their urgent surgery.

A major factor in surgical delays may be to be magnitude of the clinical workload combined with inadequate numbers of medical staff. Livingstone Hospital is a 300-bed hospital with 1 orthopaedic surgeon, 1 general surgeon, 1 obstetric and gynaecological surgeon and 3 house officers catering for the all the surgical specialties. An equivalent sized hospital in the United Kingdom would be expected to have far greater specialist and junior staffing levels to cater for the surgical workload.

It is well recognised that there are far fewer surgical procedures performed in developing world countries in comparison to wealthy countries, and that the majority of cases are obstetric or other emergency cases. This is likely to represent a gross under-provision of surgical services in these countries.[2] This audit demonstrates that even when surgery is available, there are significant delays for urgent and emergency cases that have an adverse effect on patient outcome. The next stage will be to analyse hospital processes to identify sources of delay. Surgical services need to be prioritised in this resource-limited environment to improve patient outcomes.

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Update Short Reports

CASE REPORT

A percutaneous method for blood salvage in ruptured ectopic pregnancy: experience from a Médecins Sans Frontières hospital in Ivory Coast

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SUMMARY

A simple percutaneous closed system for peritoneal blood salvage is presented that may provide more sterility and be more immediately available than traditional methods. Four patients with ectopic pregnancy were transfused with peritoneal blood, salvaged using a closed percutaneous system. Sterile abdominocentesis was performed with a 14 gauge venous cannula connected to a standard blood giving set and a 450ml blood donation pack. Successful re-transfusion followed with no adverse sequelae. This method may reduce bacterial contamination compared with salvage from an open peritoneum and be available for immediate re-transfusion without having to wait for surgical collection.

CASE REPORT

In a four-month period at the district hospital of Man, Ivory Coast, 22 patients with ectopic pregnancy were treated by laparotomy. Six patients required blood transfusion of whom four received autologous blood salvaged using a previously unpublished percutaneous closed-system siphon method. Two patients received homologous donated blood because of unsuitability of the salvaged blood. In one case there was clinical evidence of sepsis and in the second the symptoms of ectopic pregnancy rupture pre-dated the operation date by two days and the possibility of hemolysis was thought too high. A centrifuge device for detecting haemolysis was not immediately available in theatre.

Blood salvage was undertaken in the operating theatre simultaneously with fluid resuscitation and preparation for general anesthesia. The indication for immediate transfusion was hypovolaemic shock. Immediate haemoglobin estimation was often not available. Antibiotic prophylaxis with

a third generation cephalosporin was routinely administered. There were no adverse sequelae related to the transfusions and all patients were discharged home after 2 to 3 days.

DISCUSSION

Autotransfusion with unwashed blood has been shown to be a useful alternative for blood replacement, since it is available with no cross-matching and eliminates the risks and difficult supply of homologous blood.[1,2] There is growing evidence that it is at least as safe as donated blood.[3]

The previously described methods for salvage are attempted at the time of laparotomy either by gentle aspiration of blood or scooping with a gallipot or ladle into a sterile container. The blood is then passed through layers of gauze or a filter to remove clots before being anticoagulated in a citrate solution.[1,3] Even though this blood is usually defibrinated, it is possible that further clotting will occur whilst being manipulated.

The method used at the Centre Hospitalier Régional de Man utilized a 14 gauge venous cannula to perform an abdominocentesis located over the clinically established haemoperitoneum using a sterile technique and local anesthetic. A standard blood infusion set with integral 200 micron filter was connected to convey the blood (in a reverse direction) to a sterile blood collection bag containing acid-citrate-dextrose placed below the operating table. Filtered, sterile blood was then available for immediate transfusion via a new infusion set without the need to wait until surgical incision of the peritoneum. In our series there was always time to perform this procedure during the resuscitation and preparation for general anesthesia, however it is acknowledged

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(IDE = Infirmier Diplômé d'Etat)

that, in some circumstances, surgical control of bleeding must take absolute precedence, which may preclude this method of salvage. On withdrawal from the abdomen the blood is almost immediately filtered and anticoagulated, leaving little time for further clotting and wastage of salvaged blood.

It has been shown that blood collected in the traditional way at operation by aspirating or scooping with a bowl may grow "air contaminants" on blood culture.[2] Although blood culture was not available to us, a percutaneous system will avoid all contact with environmental pathogens.

A disadvantage is not being able to see the quality of the blood, but it has been noted that the history and clinical examination can be adequate to determine suitability for autotransfusion.[3] Where centrifugation is available, it should be employed on a small sample of salvaged blood to check that the supernatant is clear of free hemoglobin.

This method may also be more acceptable to Jehovah's Witnesses as the blood may be kept in total continuity with the patient as long as the blood donation pack used has at least two infusion set ports.

ACKNOWLEDGEMENTS

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CORRESPONDENCE

Lateral Intubation   Dr W. A. Lesslie, SMO, Innisfail Hospital, Queensland, Australia

Dear Sir,
With reference to your Correspondence in *Update in Anaesthesia* 23, 2007:

For eight years I have been a GP-Anaesthetist in an Australian district hospital with no specialist. In February 2008 I revisited Oshakati Hospital where I worked once in Ophthalmology and spent three days in the operationg theatre with the energetic and capable Dr Polishchuk, your correspondent. I saw and practised the method he describes of visualising the glottis - 'lateral intubation'. I had never come across it during my training or reading around the subject and I feel that it ought to be better known.

Essentially, after muscle relaxation, the patient's head is rotated to the right. The jaws are opened by the right hand (crossed middle finger / thumb worked for me). The laryngoscope blade is inserted along (above) the left border of the tongue which is already displaced down, somewhat out of the way, towards the right cheek. The glottis is lifted from below into view by an assistant.

I have seen this technique make possible a visualised intubation which the standard head-neck positioning had not allowed. I saw it once fail to save the situation, simply, I believe, for the lack of a gum elastic bougie, the standard endotracheal tube being not ideal (too curved) for this side approach. (A stylet might also have made the difference).

Editor's comment

A recent letter to the *British Journal of Anaesthesia* describes the use of a 'right molar' approach to intubate a child with Pierre Robin syndrome, cleft palate and tongue tie.[1] The right molar approach has been described previously, generally using a straight-blade laryngoscope, and termed paraglossal or retromolar intubation. The technique is identical to Dr Polishchuk's lateral intubation technique, but using access from the right side of the mouth rather than the left. I feel that the term lateral intubation may be mistaken for the act of intubating a patient in the lateral position, and suggest that left paraglossal laryngoscopy is a more appropriate description of this technique, which has proven useful to me on a number of occasions.

Reference

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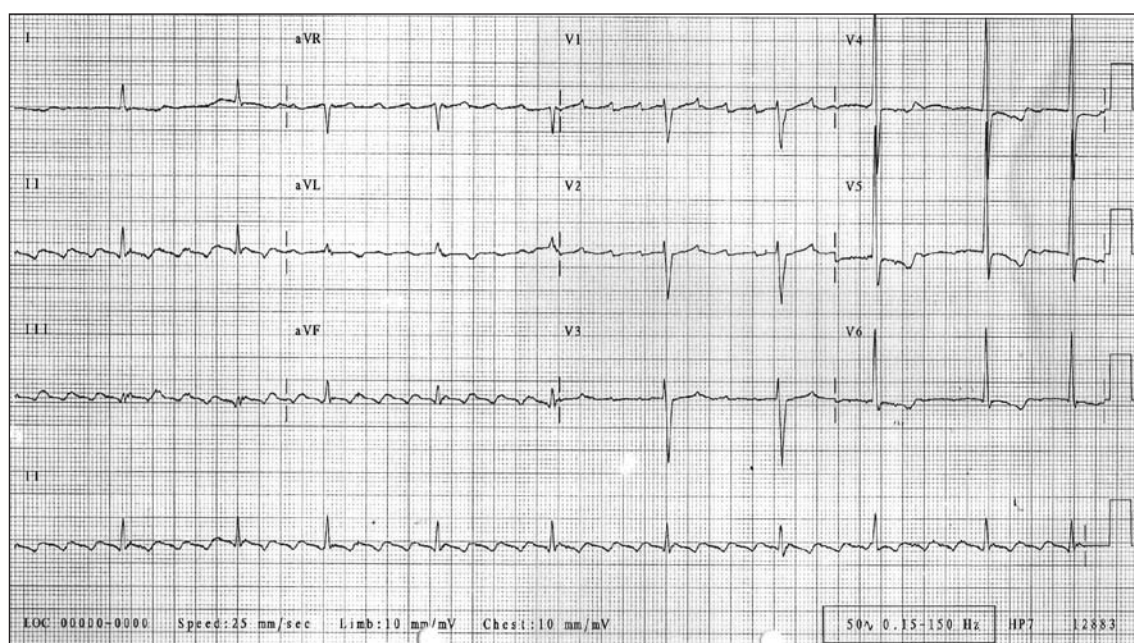
Education

Cerebral challenge

Claire Hamer, Tim Dawes*
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Case 1

A 61-year-old woman is due to undergo laparotomy for small bowel obstruction. She describes occasional palpitations over the last six months and takes digoxin 62.5mcg daily. A 12-lead ECG is performed during an episode of palpitations (Figure 1).

Figure 1.

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- **What abnormalities does this ECG show?**

- **What are your options regarding her anaesthetic management?**

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Case 2

You take over a case from a colleague - an 18-year-old who is undergoing a manipulation under anaesthesia for a forearm fracture. On removal of the laryngeal mask the patient develops fairly severe laryngospasm as she emerges from anaesthesia. Despite applying continuous positive airway pressure (CPAP) using an anaesthetic mask and breathing circuit, and administering 100% oxygen, her oxygen saturations dip down to 84%. The laryngospasm settles when you administer propofol 30mg IV and you take her to recovery. 15 minutes later the recovery nurse asks you to review your patient, who is now is short of breath, with a respiratory rate 32 breaths.min⁻¹ and SaO_2 88% on air, rising to 90% receiving oxygen at 6l.min⁻¹ via a Hudson mask. On auscultation of her chest she has bibasal crackles and you request an urgent chest X-ray (CXR).

Figure 2.

- **What does the CXR show?**
- **What is the most likely cause in this case?**
- **Name other possible causes of these CXR findings.**
- **Describe how you would manage this patient.**

Case 3

A 36-year-old woman, gravida 7 para 6, has been brought to labour ward at 36 weeks gestation, with a history of headache and neck pain. Shortly after arrival she vomited and lost consciousness. When last seen in ante-natal clinic two months previously her BP was 150/100 and methyldopa was started.

On examination she is apyrexial, her neck is stiff, Glasgow Coma Score (GCS) is 11 (Eyes 3, Motor 5, Vocal 3), pupils are 4mm and equal and reactive. Her reflexes are bilaterally brisk and her blood pressure is 197/119mmHg, heart rate 96min^{-1} and regular, and respiratory rate 20min^{-1}. Capillary venous glucose is 8.3mmol.l^{-1}. She is not in labour and the foetal heart rate is 136min^{-1}.

- **What is your differential diagnosis?**

The patient has a grand mal seizure, after which her GCS deteriorates to 5 (E1, V1, M3), BP increases to 238/139 and she requires intubation and ventilation. A CT head is performed (Figure 3).

Figure 3. *CT head without contrast*
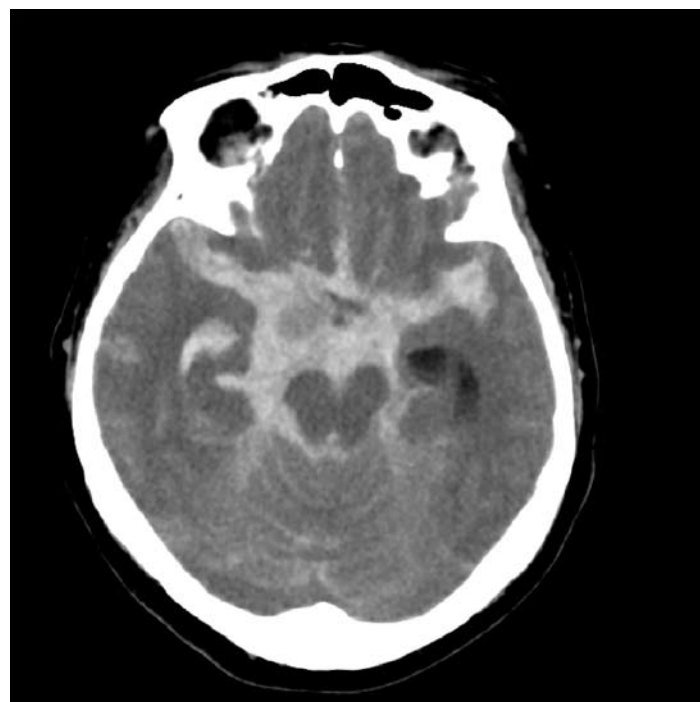
- **What does the CT show?**
- **How would you management this patient?**

DISCUSSION

Case 1

Analysis of the 12-lead ECG should be done methodically and in the same manner from patient to patient, to prevent missing abnormalities. The ECG shows atrial flutter with predominantly 4:1 block (see Figure 4). There is also ST depression in the lateral chest leads (V4-V6), which has the characteristic 'reverse tick' appearance seen with digoxin use.

Atrial flutter with a fast ventricular rate may appear similar to sinus tachycardia, atrial fibrillation and junctional tachycardias. Vagal stimuli such as carotid sinus massage and the Valsalva manoeuvre may be helpful in distinguishing these rhythms. Adenosine, where available, provides transient AV blockade which may also be helpful in discrimination.

Atrial flutter may be idiopathic or associated with cardiac abnormalities:

Management involves consideration of three factors: ventricular rate, rhythm and anticoagulation.

Ventricular rate
- Ventricular rate in atrial flutter depends on the degree of AV blockade.
- Patients with low degrees of blockade will have high ventricular rates with poor ventricular filling, poor coronary perfusion and reduced cardiac output.
- Ventricular rate can be controlled with digoxin, beta blockers or calcium channel antagonists.

Rhythm
- Reversion to sinus rhythm may be spontaneous or chemically or electrically mediated.
- It is not clear whether rhythm control decreases mortality. If tolerable to the patient, rate control, in combination with anticoagulation, is a satisfactory alternative to cardioversion.
- Electrical cardioversion involves the inherent risks of sedation or general anaesthesia, but shock energies are lower than those used in atrial fibrillation – typically an initial synchronised shock of 50J is used.
- Chemical cardioversion is most commonly achieved with flecainide or amiodarone.

Anticoagulation
- Thromboembolism is a risk although less so than in atrial fibrillation.
- Intra-cardiac clot formation may occur after 48 hours of onset of the arrhythmia - cardioversion after this period carries a risk of migration of thromboembolism to distant sites.
- Patients with paroxysmal atrial flutter or prolonged atrial flutter should be anticoagulated with warfarin, aiming to achieve an INR of 2-3.

This patient requires an urgent laparotomy. Her rate is well controlled by the digoxin she is taking. Further examination reveals that she is cardiovascularly stable with a good blood pressure. It is reasonable to proceed with a cautious general anaesthetic, knowing that you can perform a synchronised DC cardioversion if she deteriorates during the procedure. Postoperatively it would be advisable to ask a cardiologist to recommend an alternative anti-arrhythmic drug to treat her paroxysmal flutter. If this is ineffective, she should consider long-term anticoagulation.
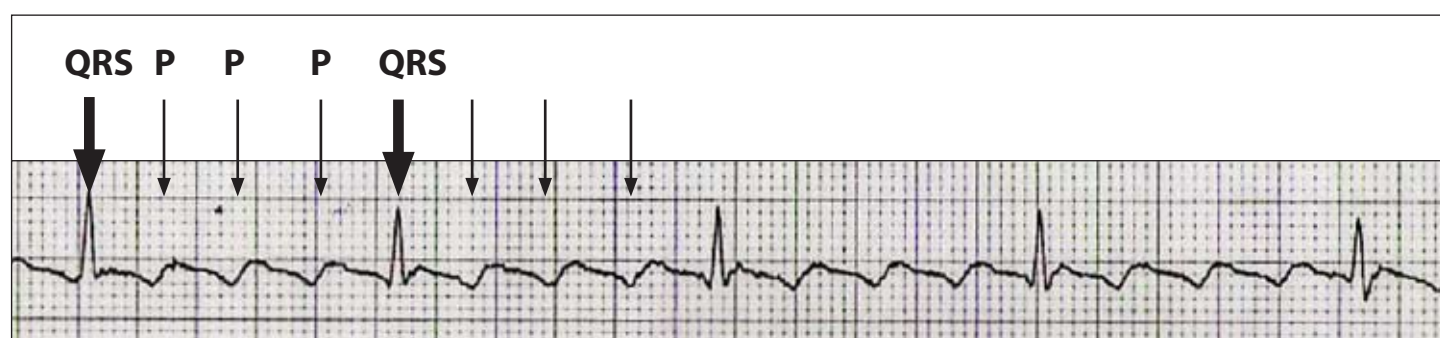

Figure 4. *The lowest strip on the ECG (the 'rhythm strip') shows continuous monitoring of lead II for the duration of the ECG. This is best used to calculate the rate and rhythm. P waves occur at a rate of 300 beats.min^{-1}, with a characteristic 'saw-tooth' appearance. The AV node fails to conduct all the P waves because of its refractory period. The QRS complexes, representing ventricular depolarisation, appear every 4th P wave. In atrial flutter, the ratio of P waves to QRS complexes is most commonly 2, 3 or 4 to 1. A supraventricular tachycardia with a ventricular rate of 150 beats.min^{-1} is commonly atrial flutter with 2:1 block*

Case 2

The chest X-ray shows bilateral fine 'alveolar' shadowing, predominantly in the mid and upper zones, that is characteristic of pulmonary oedema. In this previously fit patient, with the history of laryngospasm causing upper airway obstruction during emergence, the most likely cause is **negative pressure pulmonary oedema**. Ventilatory effort against a closed glottis generates high negative intrathoracic pressures and consequent pulmonary oedema. Patients who are septic and have sub-clinical acute lung injury may be more prone to developing this complication of anaesthesia.

Pulmonary oedema can be either cardiogenic or non-cardiogenic in aetiology.

An 'ABC' approach should be adopted, with administration of high flow oxygen (15 l.min⁻¹) via a mask with a reservoir bag. Treatment is supportive - this normally fit patient is likely to recover within a few hours. If life-threatening hypoxia or respiratory distress occurs, CPAP via a tight-fitting mask may help. Intubation and ventilation may be necessary in severe cases, if CPAP fails to help, or if the patient has significant underlying cardiopulmonary disease. Although a trial of a diuretic such as frusemide seems logical, there is no evidence that a diuresis alters the course of the illness.

Table 1. *Causes of pulmonary oedema*

Cardiogenic	Non-cardiogenic
• Left ventricular failure due to ischaemic heart disease, valvular disease or cardiomyopathy	• Adult respiratory distress syndrome • Neurogenic pulmonary oedema (following a major neurological insult such as subarachnoid haemorrhage) • Transfusion-related acute lung injury (TRALI) • Negative pressure pulmonary oedema

Case 3

The main differential diagnosis based on the patient's presentation and subsequent deterioration can be divided into diagnoses related to or unrelated to her pregnancy. The latter will depend on the endemic diseases of the region.

Related to pregancy	Unrelated to pregancy
• Preeclampsia / eclampsia	• Subarachnoid haemorrhage • Cerebral malaria • Meningitis

If CT scanning is unavailable, it can be very difficult to distinguish between subarachnoid haemorrhage (SAH) and preeclampsia/eclampsia. Three sets of blood films should be viewed to exclude malaria. The presence of proteinuria, hypertension during pregnancy and oedema would suggest preeclampsia/eclampsia. Treatment with magnesium and urgent caesarean section should be considered, since this is indicated as the primary treatment for this condition. In the absence of clinical features suggesting other diagnoses, and if there are focal neurological signs, SAH must be considered. If the mother's condition is felt to unrecoverable, again urgent caesarean section should be considered with a view to delivering the baby. This decision should be taken jointly between the obstetrician and other medical staff, after discussion with and agreement from the patient's family.

The CT head scan shows a cross section view with the patient supine. The image is best interpreted by imagining you are looking up towards the patient's head from their feet. The left side of the patient is on the right side of this image. Tissues that absorb X-rays well appear white (e.g. bone, blood), lower density tissue appears darker (e.g. air, CSF) and brain tissue looks grey.

This CT head demonstrates new blood (white) within the right lateral ventricle (A) and the basal cisterns (B). The diagnosis is subarachnoid haemorrhage, with spread of blood into the ventricular system of the brain. It is unusual to see the inferior horn of the lateral ventricles at this level (C), suggesting that the ventricular system is enlarged and that hydrocephalus is present.

This woman's prognosis is poor and by both the 'Hunt and Hess' and World Federation of Neurosurgeons scoring, she is has the worst grading (5 out of 5.)

The incidence of SAH in pregnancy is 10-20 per 100,000 pregnancies. Clinically it is difficult to distinguish SAH from pre-eclampsia (or cerebral malaria), however the presence of focal neurological abnormalities strongly suggests SAH.
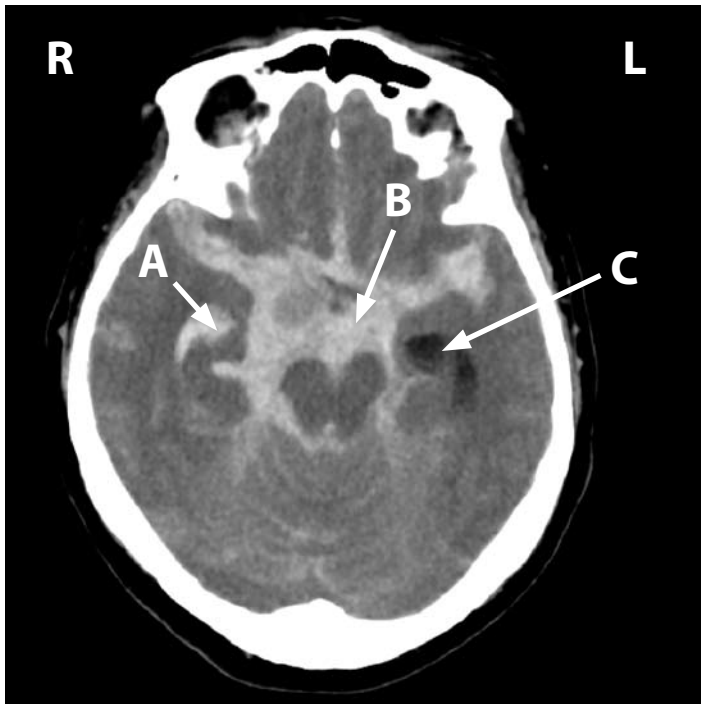
General management

Management should adopt an airway, breathing, circulation ('ABC') approach with a low threshold for intubation and ventilation. Aim to maintain an adequate cerebral perfusion pressure (CPP).

$$CPP = (ABP - CVP) - ICP$$

This can be calculated from arterial blood pressure (ABP) and intracranial pressure (ICP) where this is known. Unless ICP monitoring is available, assume ICP is 20mmHg.

Table 1. *Aetiology of subarachnoid haemorrhage (SAH)*

Ruptured arterial (berry) aneurysm(s)	• 80% aneurysms are in the anterior circulation • 15% aneurysms are bilateral
Ruptured arteriovenous malformation	
Trauma	
Hypertension	
Cocaine or amphetamine abuse	

Specific management

Secondary brain injury is minimised by preventing and aggressively treating the major complications of SAH. These are:

● *Hydrocephalus*

This patient has evidence of hydrocephalus on her CT scan and it is possible that this is contributing to her low conscious level. Where facilities exist she should have an external ventricular drain (EVD) inserted.

● *Rebleed*

The incidence of a re-bleed is 4% in first 24 hours, then 1.5% per day. The mortality in those who re-bleed is 80%.

Where available, treatment is usually considered for all patients who are grade 3 or better. This can be either operative (a titanium clip is put across the neck of the aneurysm) or radiological (a coil or coils are inserted via an endovascular route).

● *Cerebral vasospasm*

Vasospasm results from blood in the subarachnoid space, maybe oxyhaemoglobin, free radicals and lipid peroxidases and causes ischaemia and infarction of brain tissue. The risk of vasospasm is higher if the patient is female, a smoker, hypertensive and there is more blood on CT. Peak incidence is at 7-10 days and it is rare before 3 days and after 21 days post SAH.

Treatments include:

● Nimodipine – a calcium antagonist given enterally (60mg orally or via naso-gastric tube).

● Triple-H therapy (hpervolaemia, hypertension, haemodilution).

● Angioplasty (where available).

Other complications of SAH include seizures, myocardial dysfunction, neurogenic pulmonary oedema and cerebral salt wasting.

SAH in pregnant women carries a maternal mortality between 35-83% with SAH accounting for 5% of maternal deaths in the UK. If the patient fails to improve after EVD insertion to treat hydrocephalus, her prognosis is extremely poor. Consideration should be given to proceed to urgent caesarean section to deliver the baby.

From the journals

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Airway changes during labour and delivery
Kodali BS, Chandrasekhar S, Bulich LN, Topulos GP, Datta S. *Anesthesiology* 2008; **108**: 357-62

The aim of this prospective study was to evaluate airway changes in women during labour. The authors carried out two studies; the first was to photographically record the conventional Samsoon modification the Mallampati airway classification, at the onset and at the end of labour. The second study involved measuring upper airway volumes using acoustic reflectometry at the onset and conclusion of labour.

In the first study (of 61 patients) there was a significant increase in airway class from pre- to post-labour ($P<0.001$). The airway class increased one grade higher in 33% and two grades higher in 5% of women during labour. Post-labour 30 patients had an airway class of 3 or 4.

In the second study (of 21 patients) there were significant decreases in oral volume ($P<0.05$), pharyngeal area ($P<0.05$) and pharyngeal volume ($P<0.001$) after labour.

The authors conclude that clinically significant airway changes may occur during labour. Anaesthetists should not rely on pre-labour airway assessment, when planning anaesthesia during or after labour.

Antimicrobial prophylaxis against infective endocarditis
NICE guideline CG64, 17 March 2008. Available at: http://www.nice.org.uk/guidance/index.jsp?action=byID&o=11938

Since 1955 antibiotic prophylaxis has been widely used to prevent infective endocarditis in at risk patients. This practice came from an extrapolation of animal models and observational case-control studies. The assumption that antibiotic prophylaxis is effective for the prevention of infective endocarditis has never been proven.

Four existing guidelines for prevention of infective endocarditis were examined by the National Institute for Health and Clinical Excellence (NICE) to produce their own recommendations. No consistent association between an interventional procedure and developing endocarditis has been shown. The clinical effectiveness of prevention is not proven and the use of antibiotics may result in death from an adverse reaction. It is worth noting that dental procedures induce less bacteraemia than toothbrushing.

The new recommendations are that in patients with valvular heart disease, antibiotic prophylaxis is not needed to prevent infective endocarditis during

- dental procedures,

- procedures of the upper and lower gastrointestinal tract,

- procedures of the genitourinary tract; this includes urological, gynaecological and obstetric procedures, and childbirth,

- procedures of the upper and lower respiratory tract; this includes ear, nose and throat procedures and bronchoscopy.

The guidelines do not specifically look at individuals without heart lesions who are at risk of infective endocarditis (such as intravenous drug users).

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Use of the HemoCue® near patient testing device to measure the concentration of haemoglobin in suction fluid at elective caesarean section

Gupta A, Wrench IJ, Feast MJ, Alderson JD. *Anaesthesia* 2008; **63**; 531-4

Haemorrhage in obstetrics can be massive and effective resuscitation of patients relies on accurate estimation of blood loss, which can be difficult during caesarean section.

This study investigated the suitability of the Hemocue® photometer to measure the concentration of haemoglobin present in suction fluid in 30 patients undergoing elective caesarean section. Gold standard measurement of the haemoglobin concentration was taken to be laboratory analysis of the fluid. Haemoglobin concentrations obtained by each method were compared. A Bland and Altman plot indicated a good level of agreement between the two methods.

The authors also found that total blood loss, calculated by suction fluid haemoglobin concentration and weight of the surgical swabs was significantly greater than when determined by clinical estimation alone. Mean blood loss was 768ml versus 506ml respectively (*P*<0.001).

The authors concluded that Hemocue® was an accurate method of estimating haemoglobin concentration in suction fluid and that use of this measurement, to calculate intraoperative blood loss, gave consistently higher results than clinical estimation alone.

Anaesthesia chapter from Saving Mothers' Lives; reviewing maternal deaths to make pregnancy safer

Cooper GM, McClure JH. *British Journal of Anaesthesia* 2008; **100**:17-22

This article reviews the maternal mortality due to anaesthesia from the 2003-2005 Confidential Enquires into Maternal and Child Health (CEMACH) in the UK. During this period there were 6 deaths directly related to anaesthetic complications and 31 cases where poor perioperative management contributed to death. Of the six women who died, obesity was a factor in four.

The key recommendations were that:
- Better training in tracheal intubation and dealing with the consequences is required.
- Consultants must know the limits of inexperienced trainees and when they may require close supervision.
- Trainee anaesthetists must be able to obtain prompt advice and help from a designated consultant at all times.

- Morbidly obese women should not be anaesthetized by trainees without direct supervision.
- Anaesthetists should be responsible for their patients until full consciousness has returned, with stable cardiovascular and respiratory systems.
- Referral to a consultant should occur if there is any doubt about a woman's condition.

In the further 31 cases poor perioperative management may have contributed to death. These cases could be categorized into poor recognition and management of women with haemorrhage, sepsis and pre-eclampsia. Early warning scores may help identify the mother who is seriously ill and bedside estimation of haemoglobin concentration is valuable.

The effects of mild perioperative hypothermia on blood loss and transfusion requirement

Rajagopalan S, Mascha E, Na J, Sessler DI. *Anesthesiology* 2008; **108**: 71–7

This meta-analysis looked at the published randomised trials, comparing blood loss and transfusion requirements in normothermic and mildly hypothermic (34-36°C) surgical patients. Fourteen studies were included in the analysis of blood loss, and 10 in the transfusion analysis. The median temperature difference between the normothermic and hypothermic patients among the pooled studies was only 0.85°C. However, total blood loss in the hypothermic patients was 1.16 times that in the normothermic patients (*P*=0.009).

Normothermia also reduced transfusion requirement, with an overall estimated relative risk of 0.78 (95% confidence intervals: 0.63, 0.97).

In conclusion, even mild hypothermia (<1°C) significantly increases blood loss by approximately 16% (95% confidence intervals: 4–26%) and increases the relative risk for transfusion by approximately 22% (95% confidence intervals: 3–37%).

Management of inadvertent perioperative hypothermia in adults
NICE guideline CG65, 23 April 2008. Available at: http://www.nice.org.uk/guidance/index.jsp?action=download&o=40429

Inadvertent perioperative hypothermia is a common but preventable complication of perioperative procedures, which is associated with poor outcomes for patients. The National Institute for Health and Clinical Excellence in the UK has recently published guidelines on this topic. Some of the suggested techniques will not be available in, or appropriate to, all healthcare settings.

Preoperative phase - highlight the patients at risks:

- ASA grade 2 to 5 (the higher the grade, the greater the risk).

- Preoperative temperature below 36.0°C (and preoperative warming is not possible because of clinical urgency).

- Undergoing combined general and regional anaesthesia.

- Undergoing major or intermediate surgery.

- At risk of cardiovascular complications.

Perioperative care - patients (and their families and carers) should be informed that:

- Staying warm before surgery will lower the risk of postoperative complications.

- They should bring additional clothing to help them keep comfortably warm whilst in hospital.

Intraoperative phase
- The patient's temperature should be measured and documented before induction of anaesthesia and then at regular intervals until the end of surgery.

- Induction of anaesthesia should not begin unless the patient's temperature is 36.0°C or above.

- Intravenous fluids (500 ml or more) and blood products should be warmed to 37°C using a fluid warming device.

- Patients who are at higher risk of inadvertent perioperative hypothermia and who are having anaesthesia for less than 30 minutes should be warmed intraoperatively from induction of anaesthesia using a forced air warming device.

- All patients who are having anaesthesia for longer than 30 minutes should be warmed intraoperatively from induction of anaesthesia using a forced air warming device.

Postoperative phase
- The patient's temperature should be measured and documented on admission to the recovery room and then at 15-minute intervals.

- Ward transfer should not be arranged unless the patient's temperature is 36.0°C or above.

- If the patient's temperature is below 36.0°C, he or she should be actively warmed using forced air warming until they are discharged from the recovery room.

Assessment of knowledge regarding cardiopulmonary resuscitation of pregnant women
Cohen SE, Andes LC, Carvalho B. *International Journal of Obstetric Anaesthesia* 2008; **17**: 20-25

This study evaluated the knowledge of resuscitation of pregnant women amongst anaesthetists, obstetricians and emergency physicians and highlights some basic important concepts.

A 12 question survey was distributed anonymously to residents and faculty in anaesthesia, obstetrics and emergency medicine departments at Standford University Medical Centre, California. The survey was designed to look at four areas: need for left uterine displacement, advanced cardiac life support algorithms (ACLS), physiological changes of pregnancy and time to perform Caesarean section in unsuccessful resuscitation of cardiac arrest.

Knowledge of important concepts was inadequate amongst all

three specialties, and ACLS training with emphasis on special considerations for pregnant women was recommended.

Modifications to advanced cardiac life support algorithms for pregnant patients are simple and include:

- Left uterine displacement or at least 15° tilt to the left.

- Placing the rescuer's hands 1-2 cm higher on the sternum of a woman at term to obtain better cardiac output with compressions.

- Consideration of immediate caesarean delivery in a patient who has not responded after 4-5 mins of ACLS (see *Update 23*, 2007).

Guide to Contributors

Update in Anaesthesia is primarily an educational journal, which aims to provide ongoing learning and support for anaesthetists working in situations with limited resources.

Update is sent to over 3000 English-speaking anaesthetists, and read by many others including surgeons, nurses and medical students. *Update* is also translated into different languages including Spanish, Russian, French and Mandarin. After being produced in the paper format, *Update* is published on the internet (www.worldanaesthesia.org) and read by 90 people a day from more than 130 countries. *Update* is also distributed in the form of a CD-ROM, produced by the Association of Anaesthetists of Great Britain and Ireland.

Articles for consideration by the Editorial Board should be submitted as Word documents (Rich Text Format is preferred) to the Editor-in-chief, Bruce McCormick, by email at Bruce.McComick@rdeft.nhs.uk or post on CD-ROM or paper copy to Dr Bruce McCormick, Department of Anaesthesia, Royal Devon and Exeter Hospital, Barrack Road, Exeter, EX2 5DW, UK.

CLINICAL OVERVIEW ARTICLES
General considerations

- Papers must not have been published in whole or any part in another journal.

- Papers are subject to editorial revision.

- On acceptance for publication copyright becomes vested in the journal.

- Original textual matter quoted from other authors must have formal citation and be appropriately referenced.

- Some readers' first language may not be English. Please keep your text straightforward and avoid long sentences and complex terminology. Explain words and abbreviations that may not be universally standardised. Aim to include the full range of therapies available worldwide, but provide most detailed descriptions of those therapies available in resource-poor settings (see 'Management of sepsis with limited resources' in *Update 23* – www.worldanaesthesia org/component/option,com_docmantask,cat_view gid,67 Itemid,49/). Discuss older drugs as well as newer ones; halothane, thiopentone, ketamine and ether are widely used around the world.

- The article should be long enough to cover the topic in reasonable detail. Many readers will not have access to texts or journals to supplement their reading. Include text boxes and teaching points to make the layout interesting. Avoid long numbered lists with complex subdivisions. Check that your text is correct, particularly drug doses, as many readers will not be able to verify them.

Authors' details
Please supply the full forename and surname of all authors, stating their title (Anaesthetic Clinical Officer, Dr, Professor etc) and the name and address of their institution. One author should be identified for correspondence, with an email address provided.

Drug doses
Please use the international units, e.g. $mg.kg^{-1}$ rather than mg/kg. Use SI notation for g, mg, mcg etc. Please use internationally accepted non-proprietary drug names, e.g. furosemide, epinephrine and avoid trade names.

Headings
Three levels of heading may be used CAPITALS, **bold** and *italic*. Please do not employ different fonts within the text. Bullet points can be helpful.

Illustrations / figures
These may be sent to us as drawings (black on white), which we will scan into the text, or as picture files in jpg (JPEG) format. Black and white photos are also suitable. If you do not have facilities to produce drawings, contact the editor for help. If you copy illustrations from another publication please obtain copyright permission from the publishers or author. If patients appear in a photo please ensure that they have consented to this. Text accompanying illustrations should be supplied on a separate piece of paper.

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Tables
These should be prepared using the Microsoft Word table facility whenever possible.

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Graphs should be supplied using the Microsoft graph-compiling feature within Microsoft Word, or as a figure on paper.

References
A minority of Update readers have access to journals and therefore references should in general be limited to those that would be considered as 'further reading'. Please format your references as shown. Number the references in the order they appear, using the reference number as a superscript at the relevant point in the text.

References should include: names and initials of all authors (unless more than 6, when only the first 6 are given followed by 'et al.'), title of the paper; Medline abbreviation of the journal title (in italic); year of publication; volume number; first and last page numbers.

Papers accepted but not yet published should be included in the references, with the abbreviated journal name, followed by '(in press)'.

Those in preparation (including any submitted for publication), personal communications and unpublished observations should be referred to as such in the text.

1. Reynolds F, O'Sullivan G. Lumbar puncture and headache. 'Atraumatic needle' is a better term than 'blunt needle'. *Br Med J* 1998; **316**: 1018.

2. Costigan SN, Sprigge JS. Dural puncture: the patients' perspective. A patient survey of cases at a DGH maternity unit 1983–1993. *Acta Anaesthesiol Scand* 1996; **40**: 710–14.

3. Spriggs DA, Burn DJ, French J, Cartlidge NE, Bates D. Is bed rest useful after diagnostic lumbar puncture? *Postgrad Med J* 1992; **68**: 581–3.

References to books should give book title, place of publication, publisher and year; those of multiple authorship should also include chapter title, first and last page numbers, and names and initials of editors. For example:

1. Roberts F. Chapter 22: Ear, nose and throat surgery. In: Allman KG, Wilson IH, eds. Oxford handbook of Anaesthesia (1st edition) Oxford: Oxford University Press, 2001: 506-39.

UPDATE SHORT REPORTS

The scope for publication of articles describing original research and audit conducted in, and specifically relevant to, poorly-resourced settings is limited. Successful publication in major journals is rare and the distribution and accessibility of the national and regional journals that currently publish these articles is often poor. As the official journal of the World Federation of Societies of Anaesthesiologists, *Update in Anaesthesia* is the appropriate forum for publication of these manuscripts and offers a wide distribution.

The guidance above for clinical overview articles applies, with the following additional considerations.

Legal considerations

- Papers based on clinical investigation on humans should include the consent of patients and a statement of approval from an appropriate Ethics Committee. In those institutions where Institutional Review Board consent is required for the performance of audits, this should be obtained and referred to in the text.

- Avoid use of identifiable names, initials and hospital numbers of patients.

- Human subjects of case reports, research or audits should not be identifiable. Manuscripts should not disclose patients' names, initials, hospital numbers (or other data that might identify the patient(s)).

- Guides for use of tables, figures and illustrations are as described above for Clinical Overview articles.

Brief Communications

- Original investigative articles or audits of patient outcome or clinical techniques.

- Up to 1500 words (approximately 2 pages of *Update in Anaesthesia).*

- Subdivided into:
  - Summary (maximum five sentences) and key words
  - Introduction
  - Patients and methods
  - Results
  - Discussion
  - Acknowledgements
  - References – maximum 10
  - Tables and/or figures - limited to two per article.

Case Reports

- Suitable for presenting descriptive studies (a series of cases), personal experience or individual case reports of particular interest.

- Up to 800 words. One table or figure is allowed in addition to text.

- A summary may be included (up to five sentences). Division into sections is optional.

- Up to five references may be given.

Correspondence

- Welcomed on any subject, including editorials or articles that have appeared in *Update in Anaesthesia*.

- Letters may also be a suitable vehicle for presenting items of experience or observation that are too brief for Brief Communications.

- Papers describing procedures, techniques or equipment adapted by readers to their own conditions of work are welcomed.

Proofs

- Proofs are sent to the author designated to receive them. Corrections should be kept to a minimum and the proofs returned within 7 days of receipt.

The editorial team will be delighted to help with the preparation of articles. The best way of doing this is via email - Bruce.McCormick@rdeft.nhs.uk

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