

Patient Safety Update: Infusion safety, preoperative assessment, bone cement implantation syndrome

Toby Reynolds¹ and Queenie Lo²

¹Perioperative Medicine Fellow, Royal London Hospital, UK

²Patient Safety Fellow, Royal Marsden Hospital, UK

Edited by:

Isabeau Walker

Consultant Anaesthetist, Great Ormond Street Hospital London, UK



Correspondence to atotw@wfsahq.org

20th March 2018

An online test is available for self-directed Continuous Medical Education (CME). A certificate will be awarded upon passing the test. Please refer to the accreditation policy [here](#)

[Take online quiz](#)

KEY POINTS

- Drug infusion errors are preventable. System measures such as the use of a preprogrammed drug library on infusion pumps and a two-person drug checking rule, can provide additional safety barrier.
- Clear, effective communication is essential for patient safety
- Identify patients at risk of bone cement implantation syndrome, ensure all theatre team members are aware and plan accordingly

INTRODUCTION

This tutorial is based on the Patient Safety Update (PSU) published by the Safe Anaesthesia Liaison Group (SALG). SALG is a professional group with a core membership including representatives from the Royal College of Anaesthetists (RCoA), the Association of Anaesthetists of Great Britain and Ireland (AAGBI), and National Health Service (NHS) England Patient Safety. SALG's quarterly Patient Safety Updates contain learning from incidents reported to the NHS England and Wales National Reporting and Learning System (NRLS). The aim of SALG is to highlight potential or existing patient safety issues from patient stories, and to encourage incident reporting for the purpose of learning.

Cases reported to the NRLS database that are associated with severe harm or death are reviewed on a quarterly basis and form the basis of the SALG PSU. The text is changed very little from the reports of the clinicians involved – these are real stories. There are often common themes within the cases that influence the learning points highlighted. The aim of this exercise is to learn from the experience of others, and in that way we can all improve the care of our patients¹.

The cases reported are reproduced with permission from the Safe Anaesthesia Liaison Group, and were originally published on the RCoA and AAGBI websites. Further information, together with this and previous Patient Safety Updates, is available on the SALG website². The cases and much of the information contained in this tutorial is taken from the SALG Patient Safety Updates Oct 2016 – March 2017. SALG has not reviewed this publication.

INFUSION SAFETY

“A patient remained hypotensive despite maximum dose phenylephrine via peripheral cannula. A central line was inserted by the anaesthetist and noradrenaline (8mg/50mls) commenced by anaesthetist via syringe pump ... it was noted that around 15mls of 50ml syringe had been given, and that rate had been set wrong and the patient had received 15-17mls bolus. The anaesthetist was informed and the infusion was stopped immediately. The patient became hypertensive and bradycardic, then hypotensive and lost output.”

Subscribe to ATOTW tutorials by visiting www.wfsahq.org/resources/anaesthesia-tutorial-of-the-week

“A patient underwent elective robotic assisted cystectomy. The patient had pre-existing renal failure and developed metabolic acidosis and hyperkalaemia during the surgery. An IV infusion of lidocaine was used –approximately 1g administered in total. The patient became agitated post extubation, was transferred to ICU, and then had a tonic clonic seizure. The patient became bradycardic and acidotic requiring noradrenaline infusion to maintain blood pressure. LA toxicity was diagnosed and treated with intralipid. The patient improved rapidly within 20 minutes with resolution of the bradycardia and improvement in acidosis, and the noradrenaline infusion was stopped.”

Medication errors are the third most common patient safety incident reported to the NRLS³ and medication-related incidents appear frequently in SALG Patient Safety Updates. The World Health Organization launched its Third Global Patient Safety Challenge, ‘Medication without Harm’ in March 2017 to reduce the level of severe avoidable medication harm related to medications by 50% over 5 years, globally⁴. The initiative is designed for all healthcare professionals in all care settings. There are useful lessons for anaesthetic practice in the WHO Patient Safety Curriculum Guide⁵, including an emphasis on clear communication (such as encouragement to “state the obvious”), personal aide-memoires and routine use of careful checks.

The Patient Safety Curriculum also describes the complex systems we work in, and the importance of understanding the multiple system factors that make it possible for error to occur (patient and provider factors; task factors; technology and tool factors; team factors; environmental factors; organizational factors). Human errors such as slips, lapses, mistakes and violations interact with system factors such as inadequate communication, lack of checking procedures and time pressures as well as suboptimal workplace and medication packaging design.

Violation of strict checking rules may be more common than we care to think⁶ (do you check/double check the name and expiry date of every ampoule of every drug that you give?). We need to think about the way that we work as individuals, as well as controlling the environment in which we work (rushed, noisy, multiple tasks undertaken at the same time), to help us to reduce errors.

Vasoactive and analgesic drug infusions

The use of powerful agents or concentrated solutions in anaesthesia such as sedatives, analgesics or inotropes exacerbates the problems associated with infusion errors. Errors associated with infusions include:

- Inadvertent bolus administration
- Siphonage and free flow
- Occlusion, and subsequent post-occlusion bolus delivery⁷

Syringe-driver pumps, the most commonly used pumps for vasoactive drugs in anaesthesia practice, are usually programmed to depress a syringe plunger at a set rate of mm/hr, and thus putting in a syringe with the wrong cross-sectional area will deliver the wrong volume in a given time. Although many pumps have safety systems designed to automatically detect the type of syringe that has been loaded, these are not fool proof. Use of a **pre-programmed drug library**, as opposed to setting a generic administration rate in ml/hr, can help avoid errors in dose calculation, although this requires an institution to keep the pump’s drug library up to date to avoid violation errors. Involving a colleague as a **second person to check** the pump settings and dose calculations provides an additional safety barrier.

Of particular relevance for high potency infusions is the delivery of a bolus dose as a result of a complete or partial occlusion of the infusion line, or other interference with the depression of the syringe plunger. Although the infusion fluid itself is incompressible, air bubbles in the syringe and the elasticity of the infusion line tubing add a small amount of compliance to the system that allows a brief period of continued drug infusion after occlusion of the line, which is then delivered to the patient as a bolus when the occlusion is removed. The more distal the occlusion is to the pump and the higher the pump operating pressure, the greater the magnitude of this post-occlusion bolus. Clinicians investigating an incident of inadvertent hypertension during noradrenaline administration noted accidental boluses of almost 1ml in a simulation study that added additional compliance in the system, such as a piece of infusion tubing accidentally stuck between the plunger and the syringe driver⁸.

Finally, an extremely important source of error in anaesthesia is to forget to **clear the drug line after the infusion** has been completed – for instance an extension used for a remifentanyl or atracurium infusion.

Lidocaine infusions

Perioperative use of intravenous lidocaine infusions for analgesia during and after surgery has gained popularity in recent years. Scientific literature suggests that lidocaine is a useful adjuvant analgesic with predictable pharmacokinetics, but it is nonetheless a drug with a narrow therapeutic range, with central nervous system (CNS) toxicity occurring only slightly above the therapeutic plasma level.

The dose of intravenous lidocaine suitable for analgesia in the perioperative period is 1–2 mg kg⁻¹ as an initial slow bolus followed by a continuous infusion of 0.5–3 mg kg⁻¹h⁻¹. The free plasma concentration of lidocaine is determined by the total dose and rate of injection, but is also affected by the acid–base status, hypercapnia and hypoxia, low plasma protein levels, and diminished hepatic or renal function. All these factors need to be taken into account when calculating the dose to be given⁹.

A recent review of 45 small randomized controlled trials suggested that systemic perioperative lidocaine infusion was not associated with increased major adverse events, but noted that current data were underpowered to definitively exclude this risk¹⁰.

The authors of one review note that in their experience lidocaine toxicity is almost always a result of an iatrogenic error in dose, delivery, or infusion pump programming⁹. In the case described here, the rapid response to intralipid therapy suggests that the plasma levels of lidocaine may have been toxic for this patient.

COMMUNICATION AND PREOPERATIVE ASSESSMENT SAFETY

“A patient was undergoing eye examination under a general anaesthetic. He suffered a sudden desaturation, and required transfer to critical care, ventilated and sedated, and later required emergency placement of chest drain which drained large volumes of pleural fluid. A CT scan that was performed and reported prior to the eye examination had demonstrated a large pleural effusion with mediastinal shift.”

The ultimate responsibility for ensuring that a patient has been assessed adequately prior to surgery rests with the anaesthetist who will give the anaesthetic (AAGBI Preoperative Assessment and Patient Preparation 2010)¹¹. However, system factors may contribute to failings in preoperative assessment and preparation. Time is one important factor. Your organisation has a responsibility to make sure that you receive notification about elective lists in good time so that you can assess the patient without undue pressure. Although not specifically mentioned in the AAGBI guideline, it makes intuitive sense that the organisation should also provide space to see the patient, and make sure that you have access to any relevant medical records.

Missing medical records and difficulty accessing relevant test results was a common theme in a 2000 analysis of the Australian Incident Monitoring Study database. That study found that poor communication contributed to 46 of 197 incidents related to preoperative assessment, most commonly through missing records and organisational system factors such as failure to communicate orders¹². Similarly, a qualitative interview study in the UK found that information transfer between surgeons, anaesthetists and preoperative assessment teams was often poor, particularly regarding the results of specialist assessments¹³. Another study in surgical outpatient clinics in the UK found that 15% of patients had missing clinical information that the surgeon looked for but couldn't find, most commonly imaging results, diagnostic test results and recent summaries of recent admissions¹⁴.

While it is hard for any individual clinician to change these system factors, awareness of the problem is important as it can help limit risks. Communication breakdown was found to be the second most common contributing factor in a series of surgical error reports analysed in the United States, after inexperience/ lack of competence. Importantly, miscommunication was reported as a contributing factor twice as often where the surgeon also reported excessive workload¹⁵.

A more detailed study of U.S. malpractice claims identified status asymmetry, ambiguity of roles and handovers as the three most common contributing factors to communication breakdowns that had led to injury to surgical patients¹⁶.

Communication tools can be used to minimise the risk of important information being missed. The most obvious example of this is the WHO checklist, which has been shown to reduce death and complications in both high- and low-resource settings. Despite initial misgivings, the WHO Checklist has now become an accepted part of operating theatre routine in many countries, and probably has had its greatest impact in improving adherence to routine safety checks, and by improving teamwork and communication^{17,18}. However, imposition of checklists and formal communication tools will not eradicate perioperative communication errors without effective implementation – effective use of safety checks requires understanding of the benefits, appropriate training and good surgical leadership^{5,18,19}. Teamwork training, structured reflection using simulated and real clinical episodes and adoption of a systems approach may be useful²⁰.

BONE CEMENT IMPLANTATION SYNDROME

Bone cement implantation syndrome (BCIS) is a poorly understood phenomenon with no agreed standard definition currently. It is characterised by hypoxia and hypotension but has a wide spectrum of clinical features that can occur with any surgical instrumentation of the femoral canal, ranging from transient desaturation and hypotension to pulmonary hypertension and cardiac arrhythmias. A sudden drop in end tidal CO₂ may herald abrupt onset pulmonary hypertension and a precipitous drop in cardiac output resulting in cardiac arrest²¹. BCIS is described in tutorial 351²².

BCIS is associated with procedures that breach the femoral canal such as intramedullary nailing and cemented and uncemented hip implants. Frail patients undergoing cemented hip replacement surgery following hip fracture are at particularly high risk. Interventions which may reduce the likelihood or severity of bone cement implantation syndrome include medullary lavage, good haemostasis before cement insertion and retrograde application of cement with the cement gun²¹.

“A patient was hypoxic and hypotensive after bone cement was inserted. This resolved to some extent but the patient had to be intubated in recovery and taken to ICU. Following local case review, the department identified and reported some good practice points:

- *Identify high risk patients*
- *Cement implantation syndrome was not discussed within the surgical or anaesthetic consent process. This should probably be done and documented in patients who are high risk.*
- *Communication between the surgical and anaesthetic teams was good however the cementing was not discussed at the WHO check*
- *The cement curfew did not take place formally, we just discussed it around the time of cementing. Guidance should be available in theatre on how exactly this should be done to standardise this.”*

The AAGBI published a guideline on bone cement implantation syndrome in 2015, which provides a structured approach to management of patients requiring cemented hemiarthroplasty following a long bone fracture²³. In the above case, the local review panel noted that some of the recommended steps had not been completed, such as identification of the at-risk patient and shared team understanding of the problem. Clinicians in Coventry recommend a ‘Cement Curfew’ which teams might like to consider²⁴.

The AAGBI guideline recommends the following steps to minimise the impact of BCIS:

1. Identification of patients at high risk of cardiorespiratory compromise:
 - Increasing age
 - Significant cardiopulmonary disease
 - Diuretics
 - Male sex
2. Preparation of team(s) and identification of roles in case of severe reaction
 - Pre-operative multidisciplinary discussion
 - Pre-list briefing and World Health Organisation (WHO) Safe Surgery checklist ‘time-out’ (Reference)
3. Specific intra-operative roles:
 - Surgeon
 - Inform the anaesthetist just before insertion of cement
 - Wash and dry the femoral canal
 - Apply cement retrogradely using the cement gun with a suction catheter and intramedullary plug in the femoral shaft
 - Anaesthetist
 - Ensure adequate resuscitation pre-and intra operatively
 - Confirm to the surgeon that you are aware that he/she is about to prepare/apply cement
 - Maintain vigilance for signs of cardiorespiratory compromise
 - Aim for a systolic blood pressure within 20% of pre-induction value. Invasive blood pressure monitoring is indicated for patients at higher risk
 - Prepare vasopressors in case of cardiovascular collapse

The ‘Cement Curfew’ mentioned above refers to a protocol described by a team in Coventry in the UK, whereby team members are given pre-assigned roles for the period of the operation when BCIS is most likely and attention is focused on readying the patient for this possible event, and monitoring for signs of a problem.

SUMMARY

- Drug infusions are a common source of preventable errors. Users should be familiar with pump programming and the possibility of unintended boluses
- Plasma lidocaine concentrations are related to the total dose and infusion rate, but also to other factors such as acid base status and protein binding
- Communication breakdown is a common source of surgical and anaesthesia error
- Bone cement implantation syndrome is characterised by hypoxia and hypotension around the time of cement implantation in the femoral canal, but can lead to cardiovascular collapse. It is important to identify patients at risk and to plan accordingly, making all the theatre team aware.

This tutorial is estimated to take 1 hour to complete. Please record time spent and report this to your accrediting body if you wish to claim CME points.

To take the online test accompanying this tutorial, please click [here](#)

REFERENCES AND FURTHER READING

1. Macintosh R. Deaths under anaesthetics (1949) *BJA* 21:107-36
2. Safe Anaesthesia Liaison Group. <https://www.rcoa.ac.uk/node/25928> (accessed Nov 13, 2017)
3. NHS Improvement. National quarterly data on patient safety incident reports: March 2017 <http://bit.ly/2qY5MI6> (accessed Nov 13, 2017)
4. World Health Organisation. Medication Without Harm. <http://www.who.int/patientsafety/medication-safety/en/>
5. World Health Organisation. Patient Safety Curriculum Guide. http://www.who.int/patientsafety/education/mp_curriculum_guide/en/
6. Smith, A. F., Goodwin, D. S., Mort, M. and Pope, C. (2005), Anaesthetists' violations of safety guidelines. *Anaesthesia*, 60: 201–202. doi:10.1111/j.1365-2044.2004.04092.x
7. Keay, S, Callander, C. The safe use of infusion devices, *Continuing Education in Anaesthesia Critical Care & Pain*. 2004; 4:81–85, <https://doi.org/10.1093/bjaceaccp/mkh022>
8. Snijder, R, Knape, J, et al. Hypertensive Crisis During Norepinephrine Syringe Exchange: A Case Report. *A&A Case Reports*: 2017; 8:178–181 doi: 10.1213/XAA.0000000000000458
9. Eipe N, Gupta S, Penning J. Intravenous lidocaine for acute pain: an evidence-based clinical update. *BJA Education*, 2016; 16 292–298. doi: 10.1093/bjaed/mkw008
10. Weibel S, Jokinen J *et al.* Efficacy and safety of intravenous lidocaine for postoperative analgesia and recovery after surgery: a systematic review with trial sequential analysis. *BJA* 2016; 118:770–783 <https://doi.org/10.1093/bja/aew101>
11. Association of Anaesthetists of Great Britain and Ireland 2010 Pre-operative Assessment and Patient Preparation. The Role of the Anaesthetist 2 (<http://bit.ly/2q5RsfA>).
12. Kluger MT, Tham EJ *et al.* Inadequate pre-operative evaluation and preparation: a review of 197 reports from the Australian Incident Monitoring Study. *Anaesthesia*. 2000; 55: 1173–1178. doi:10.1046/j.1365-2044.2000.01725.x
13. Nagpal K, Arora S, *et al.* Failures in communication and information transfer across the surgical care pathway: interview study. *BMJ Qual Saf* 2012 [online first]. doi: 10.1136/bmjqs-2012-000886
14. How safe are clinical systems? Health Foundation. 2011 (http://www.health.org.uk/sites/health/files/HowSafeAreClinicalSystems_fullversion.pdf)
15. Gawande AA, Zinner MJ, *et al.* Analysis of errors reported by surgeons at three teaching hospitals. *Surgery* 2003;133:614-21
16. Greenberg CC, Regenbogen SE, *et al.* Patterns of communication breakdowns resulting in injury to surgical patients. *J Am Coll Surg*. 2007; 204:533-540
17. Walker IA, Reshamwalla S, Wilson IH; Surgical safety checklists: do they improve outcomes? *BJA* 2012;109:47–54 <https://doi.org/10.1093/bja/aes175>
18. Bergs J, Hellings J *et al.* Systematic review and meta-analysis of the effect of the World Health Organization surgical safety checklist on postoperative complications. *BJS* 2014; 101:150-158. (<http://onlinelibrary.wiley.com/store/10.1002/bjs.9381/asset/bjs9381.pdf?v=1&t=ic66zl6c&s=56b34d8d1582c56fd7fe1cb834fb95e067be22e0>)
19. Bergs J, Lambrechts F *et al.* Barriers and facilitators related to the implementation of surgical safety checklists: a systematic review of the qualitative evidence. *BMJ Qual Saf*. Published on line July 2015 (<https://www.zorgneticuro.be/sites/default/files/general/BMJ%20Qual%20Saf%202015%20Bergs.pdf>)
20. McCulloch P, Morgan L, New S *et al.* Combining systems and teamwork approaches to enhancing the effectiveness of safety improvement interventions in surgery: the safer delivery of surgical services (S3) program. *Annals Surg*. 2017; 265: 90-96
21. Donaldson AJ, Thomson HE *et al.* Bone cement implantation syndrome, *BJA* 2009; 102: 12–22, <https://doi.org/10.1093/bja/aen328>
22. So D, Yu C and Doane MA. Tutorial 351 - Bone cement implantation syndrome. *ATOTW* 2017. (<http://www.wfsahq.org/resources/anaesthesia-tutorial-of-the-week>)
23. Griffiths R *et al.* Guideline: reducing the risk from cemented hemiarthroplasty for hip fracture. *Anaesthesia* 2015; 70:623-626
24. Scrase A, Horwood G, Sandys S. Coventry “Cement Curfew”: team training for crisis. *Anaesthesia News* 2014; 327:8–9 https://www.aagbi.org/sites/default/files/ANews_October_Web_0.pdf



This work by WFSA is licensed under a Creative Commons Attribution- NonCommercial-NoDerivatives 4.0 International License. To view this license, visit <https://creativecommons.org/licenses/by-nc-nd/4.0/>