CASE REPORT

Catastrophic cement reaction following cementation for megaprosthesis for proximal femoral fracture

Muhammad Nouman Baig,¹ William Curtin,¹ Michael Andrew Callaghan,² Colin G Murphy¹¹Department of Trauma and Orthopaedics, Galway University Hospital, Galway, Ireland²Department of Anaesthesia, Galway University Hospital, Galway, Ireland

Correspondence to

Dr Muhammad Nouman Baig, nouman142@gmail.com

Accepted 13 September 2017

SUMMARY

Bone cement implantation syndrome (BCIS) is a well-described and potentially fatal complication of orthopaedic surgery involving pressurised bone cement. Although also described for certain spinal procedures, it is most commonly associated with cemented hip and knee arthroplasty and with cemented hemiarthroplasty following neck of femur fracture in particular.

Donaldson *et al* proposed the definition of BCIS as a syndrome "characterized by hypoxia, hypotension or both and/or unexpected loss of consciousness occurring around the time of cementation, prosthesis insertion, reduction of the joint or, occasionally, limb tourniquet deflation in a patient undergoing cemented bone surgery". Other features include increased vascular resistance, cardiac arrhythmias and cardiac arrest post cement use.

We describe a case of a patient who suffered a catastrophic reaction to cement during surgery for a comminuted proximal femoral fracture.

BACKGROUND

The clinical syndrome of bone cement implantation syndrome (BCIS) typically occurs at the time of bone cementation and insertion of the prosthesis. Although not fully understood, the pathophysiology of BCIS is thought to involve a number of pathways, including anaphylaxis, pulmonary embolisation, complement activation and histamine release, combining to increase pulmonary vascular resistance, and potentially ventilation/perfusion mismatches with resultant acute hypoxia, right ventricular failure and cardiogenic shock.^{1–5} The true incidence of cardiac arrest secondary to BCIS is difficult to ascertain, but has been postulated in a study by Parvizi *et al*⁶ to be 0.14%–0.68% for cemented total hip arthroplasty (THA) and for cemented hemiarthroplasty 0.4%–4.3%.

Deaths from cemented prostheses are higher than for uncemented prostheses at 24 hours according to a study based on the National Hip Fracture Database,⁷ echoing the findings from the Anaesthetic Sprint Audit of Practice.⁸ A study from Sweden quotes the incidence of BCIS for cemented hemiarthroplasty as high as 28%, and one from Norway of grade 3 BCIS of up to 1.7%.^{9 10}

Predictive risk factors for BCIS identified by Olsen *et al*⁹ include higher American Society of Anaesthesiologists (ASA) grades, chronic obstructive airway disease, diuretics and warfarin, while

lower preoperative mobility status is associated with higher early venous thromboembolism rate following cemented hemiarthroplasty.¹¹

The use of a proximal femoral replacement megaprosthesis (or modular endoprosthesis) is controversial for proximal femoral fractures, but may be considered for patients in the context of highly comminuted proximal femoral fractures with subtrochanteric extension, in osteoporotic bone, by surgeons with appropriate experience. This confers a stable construct which allows patients to mobilise fully weight bearing immediately following surgery, thus obeying UK Blue Book Standards (2007) and Irish NCPTOS guidelines (2015).^{12 13}

CASE PRESENTATION

We describe a case of a frail 83-year-old female who was brought to the emergency department following a witnessed fall, after which she was unable to stand or walk because of pain and tenderness in thigh and groin region. Radiographic investigations revealed a comminuted intertrochanteric fracture with subtrochanteric extension (figures 1–3).

The patient had multiple comorbidities including hypertension, atrial fibrillation, hypercholesterolaemia, osteoporosis and previous left parietal cerebral infarct. Her regular medications included a B-blocker, statin, diuretics, warfarin and digoxin. Her international normalisation ratio (INR) was 2.4 on arrival. In the emergency department, skin traction was applied via a Thomas splint and analgesia was commenced. Warfarin was discontinued and vitamin K was administered orally. Subcutaneous low-molecular-weight enoxaparin was administered at prophylactic dosage, early preoperative anaesthetic assessment and investigations were obtained, and informed consent for surgery was obtained from the patient in conjunction with her family. Despite the Thomas splint, femoral block and multimodal oral and intravenous analgesia pain control was problematic, particularly when the patient moved in the bed for nursing or toileting. On the fourth morning following admission, the patient's INR was acceptable (INR 1.2) and she was taken to theatre.

Following discussion between the patient, surgeon and anaesthetist, and in view of the potential for large blood loss and a prolonged procedure, it was decided to administer a general anaesthetic with a fascia iliaca three-in-one nerve block postoperatively for analgesia. The patient was declared

CrossMark

To cite: Baig MN, Curtin W, Callaghan MA, *et al*. *BMJ Case Rep* Published Online First: [please include Day Month Year]. doi:10.1136/bcr-2017-220158

Figure 1 Antero posterior pelvis preoperative.

ASA grade 3E. Induction of anaesthesia was uneventful. The patient was intubated and mechanically ventilated and anaesthesia was maintained with nitrous oxide and sevoflurane. A radial arterial line was inserted preinduction and invasive arterial blood pressure was monitored throughout the procedure, along with ECG, pulse oximetry and end-tidal carbon dioxide. She was haemodynamically stable throughout induction and for about the first 1.5 hours of anaesthesia, with no requirement for vasopressor or inotropic support at any stage.

Figure 2 Antero posterior of left hip preoperative.

Figure 3 Lateral of the left hip demonstrating highly comminuted fracture of the left proximal femur in osteopenic bone.

About 45 min into the procedure, the transverse ‘guillotine’ osteotomy below the level of the subtrochanteric fracture had been completed, with the distal cortical surface prepared with a reamer. In addition, using the multiple fracture lines already in situ, the greater trochanter was bivalved and fashioned to accept the shoulder of the prosthesis, as per a standard extended trochanteric osteotomy, in preparation for cementation. A trial proximal femur was assembled and inserted to assess limb length, rotation and stability of the hip joint. Following appropriate communication with theatre and anaesthetic teams prior to cementation, a cement restrictor was inserted, and cement inserted using a cement gun in preparation for the assembled modular prosthesis. Of note at this point, the patient had received 2 L of intravenous crystalloid solution and there had been minimal blood loss. She was haemodynamically stable and normothermic. An arterial blood gas sample just prior to bone cement showed a haemoglobin of 9.4 g/L and serum lactate of 0.9 and a normal pH, suggesting adequate tissue perfusion. Immediately following cement insertion, the patient developed simultaneous bradycardia and hypotension, precipitous drop in end-tidal carbon dioxide, suggesting a marked drop in cardiac output. Atropine, ephedrine and a fluid bolus were administered, followed by epinephrine boluses. Within 1 min, the blood pressure was 50/30 mm Hg and oxygen saturation 70% despite an Fio₂ of 1.0. Asystolic cardiac arrest ensued within a further 30 s. Surgery was immediately ceased, the patient turned supine and cardiopulmonary resuscitation was commenced as per ACLS (Advanced cardiac Life Support) protocols. Full resuscitation was continued for 20 min, but there was no return of spontaneous circulation and the patient was declared dead.

DISCUSSION

Methyl methacrylate is a methyl ester of methacrylic acid. Its chemical name is $\text{CH}_2=\text{C}(\text{CH}_3)\text{COOCH}_3$, and in its polymerised form, polymethyl methacrylate (PMMA), it is used as a cement or grout in dentistry and orthopaedics.¹⁴ In orthopaedics, the cement is most commonly used for implant fixation, vertebroplasty, kyphoplasty and sometime as spacer. The first use of PMMA was by a British surgeon John Charnley who in 1958 used it in hip arthroplasty.

It has been suggested that embolisation of fat, cement particles, marrow, air and fibrin aggregates takes place secondary to cementation and that prosthesis insertion then generates

Table 1 The bone cement implantation syndrome severity classification proposed by Donaldson *et al* (Bone cement implantation syndrome. *Br J Anaesth* 2009;102:12–22). CVS, cardiovascular; SBP, systolic blood pressure.

Grade	Hypoxia	Hypotension	Loss of consciousness
1	Moderate SpO ₂ <94%	SBP fall >20%	Alert
2	Severe SpO ₂ <88%	SBP fall >40%	Loss of consciousness
3	CVS collapse	CVS collapse	CVS collapse

high intramedullary pressure, up to 597 kPa,^{15–17} which causes systemic and cardiopulmonary effects. This condition, termed BCIS can cause disastrous haemodynamic effects including precipitous drop in mean arterial pressure, tachycardia, pulmonary hypertension, pulmonary oedema, bronchoconstriction, hypoxemia, cardiac arrhythmias, cardiogenic shock, cardiac arrest and death.^{18–20} Donaldson *et al* proposed three grades of BCIS, based on the severity of symptoms relating to hypoxia, hypotension and loss of consciousness (table 1).

Some patient-specific and implant-specific factors have been implicated in increasing the incidence of BCIS. Patient-related factors include old age, decreased physical reserves, pathological fractures, poor bone quality, osteoporosis, pulmonary hypertension and impaired cardiac functions. Implant-related factors include long femoral components.¹⁷

There are some precautions which can be adapted to reduce the risk of BCIS-induced morbidity and mortality.²¹ The anaesthetic team should be involved in planning and preoperative optimisation of patients at risk of BCIS, with sufficient time taken to investigate and manage patients for their comorbidities and to optimise them for the stress of anaesthesia and surgery. There should be proper communication between surgical and the anaesthetic teams before and during surgery, especially just prior to cementation. Optimal oxygenation, ventilation and volume resuscitation should be established prior to cementation to reduce the risks of BCIS, and patients should be monitored closely for cardiorespiratory collapse during cementation (although in spite of these measures our patient succumbed). The risk of BCIS can be reduced by the use of uncemented prosthesis, or if cementing, by preparation of cement in vacuum when compared with room air and by cortical venting reduce the intramedullary pressurisation of the cement.²¹

The idea of a ‘cement curfew’ was pioneered by University Hospital Coventry anaesthesia department^{21 22} and describes not only the best practice for theatre, with a specific pause or time out preoperatively, but also the roles the operating surgeons, anaesthetic team and the nursing staff have at the time of cementation and prosthesis insertion. This has been found to be very helpful step in deterring or decreasing chances of any unforeseen circumstances related to cementing.

Up to 10% of patients presenting with hip fractures have concurrent medical comorbidities necessitating anticoagulation with warfarin. Delays to theatre beyond the 48 hours window are most often due to patient factors (anticoagulation and infection) and implant factors (ordering, in particular, implants and ancillary equipment). As highlighted by Lawrence *et al*²³, ‘This coagulopathy must be reduced or eliminated before surgery can safely be performed. The time taken to achieve a safe INR together with the presence of multiple comorbidities has the potential to delay surgical treatment, which conflicts with policy initiatives (such as the 2010 ‘Best Practice Tariff’ in the UK) that aim to improve patient outcomes by reducing delays in hip fracture surgery to less than 48 or 36 hours’.

Figure 4 Schematic diagram of the DePuy Limb Preservation System (Warsaw, IN, USA), the prosthesis utilised in this case.

Megaprosthesis arthroplasty was introduced in 1980s but started to gain popularity in late 1990s. The initial megaprosthesis designs were monolithic but newer models are modular. The modular megaprosthesis (also called modular endoprosthesis) consists of number of components which can be assembled in various combinations according to joint, bone type, length, offset and rotation (figure 4). The main indications for modular endoprosthesis use include bone tumours, metastatic bone disease, failed arthroplasty, fractures and non-union of fractures with massive bone loss and/or poor bone stock. Although controversial, we feel the choice of a proximal femoral replacement for this patient is justified due to the extensive comminution and pain of this particular fracture, as it would

Learning points

- Surgeons, anaesthetists and all theatre staff must be aware of bone cement implantation syndrome (BCIS), and in particular the high frequency (up to 40% according to Olsen) with which it occurs during procedures involving cemented prostheses.
- Risk profiling should be undertaken preoperatively to anticipate the risks based on patient-specific and implant-specific factors.
- Surgical and anaesthetic team should work closely in identifying high-risk patients and optimise them before surgery.
- During the case, forewarned is forearmed, and all parties must remain vigilant, especially during the period of time around cementation, to recognise and manage signs of BCIS. A Coventry-style curfew is an excellent addition to theatre protocol.
- It highlights the expanding role of reconstructive arthroplasty within hip fracture surgery and the risks this entails. Patients presenting with hip fractures can be complex, their treatment and surgery is not straightforward.

allow full immediate postoperative weight bearing and confer a stable joint. The extension of the use of modular endoprosthesis into trauma, for fractures or periprosthetic fractures with extensive bone loss has been reported with good results, for both the proximal and distal femur.^{24 25} The main advantages cited are of early return to full immediate weight bearing, with good stability and mobility of the joint.^{26–30} Although costly, and demanding a combination of skill sets for the surgeon covering arthroplasty, reconstruction and trauma, the use of modular endoprosthesis in this context is expected to rise.

Although unreported in the context of megaprosthesis usage, this case highlights the risks associated with cementation of a prostheses for fragility fracture of the proximal femur.

Contributors All authors contributed to the manuscript as follows: MNB and CGM: conception, design, analysis and interpretation of data. MNB, CGM, WC and MAC: drafting the article. MNB, CGM, WC and MAC: revising it critically for important intellectual content. MNB, CGM, WC and MAC: final approval of the version to be published. All authors read and approved the final manuscript.

Competing interests None declared.

Patient consent Obtained.

Provenance and peer review Not commissioned; externally peer reviewed.

© BMJ Publishing Group Ltd (unless otherwise stated in the text of the article) 2017. All rights reserved. No commercial use is permitted unless otherwise expressly granted.

REFERENCES

- Donaldson AJ, Thomson HE, Harper NJ, *et al.* Bone cement implantation syndrome. *Br J Anaesth* 2009;102:12–22.
- Lamadé WR, Friedl W, Schmid B, *et al.* Bone cement implantation syndrome. A prospective randomised trial for use of antihistamine blockade. *Arch Orthop Trauma Surg* 1995;114:335–9.
- Ereth MH, Weber JG, Abel MD, *et al.* Cemented versus noncemented total hip arthroplasty-embolism, hemodynamics, and intrapulmonary shunting. *Mayo Clin Proc* 1992;67:1066–74.
- Pitto RP, Blunk J, Kössler M. Transesophageal echocardiography and clinical features of fat embolism during cemented total hip arthroplasty. A randomized study in patients with a femoral neck fracture. *Arch Orthop Trauma Surg* 2000;120:53–8.
- Urban MK, Sheppard R, Gordon MA, *et al.* Right ventricular function during revision total hip arthroplasty. *Anesth Analg* 1996;82:1225–9.
- Parvizi J, Holiday AD, Ereth MH, *et al.* The Frank Stinchfield Award. Sudden death during primary hip arthroplasty. *Clin Orthop Relat Res* 1999;369:39–48.
- Talsnes O, Vinje T, Gjertsen JE, *et al.* Perioperative mortality in hip fracture patients treated with cemented and uncemented hemiprostheses: a register study of 11,210 patients. *Int Orthop* 2013;37:1135–40.
- ASAP - Anaesthetic Sprint Audit of Practice 2014 | AAGBI, 2014. <https://www.aagbi.org/news/asap-anaesthetic-sprint-audit-practice-2014> (cited 28 Nov 2016).
- Olsen F, Kotyra M, Houltz E, *et al.* Bone cement implantation syndrome in cemented hemiarthroplasty for femoral neck fracture: incidence, risk factors, and effect on outcome. *Br J Anaesth* 2014;113:800–6.
- Gjertsen JE, Lie SA, Vinje T, *et al.* More re-operations after uncemented than cemented hemiarthroplasty used in the treatment of displaced fractures of the femoral neck: an observational study of 11,116 hemiarthroplasties from a national register. *J Bone Joint Surg Br* 2012;94:1113–9.
- Murphy CG, Moran DE, Gerstenmaier JF, *et al.* Evaluation of the incidence of pulmonary embolism in the early postoperative period following cemented hemiarthroplasty. *Hip Int* 2016;26:295–300.
- British Orthopaedic Association (BOA) and British Geriatrics Society (BGS). The care of patients with fragility fracture. 2007 http://www.bgs.org.uk/pdf_cms/pubs/Blue%20Book%20on%20fragility%20fracture%20care.pdf
- National Clinical Programme for Trauma and Orthopaedic Surgery. National Model of Care for Trauma and Orthopaedic Surgery. 2015 <http://www.hse.ie/eng/about/Who/clinical/natclinprog/orthopaedicsprogramme/>
- Vaishya R, Chauhan M, Vaish A. Bone cement. *J Clin Orthop Trauma* 2013;4:157–63.
- Mudgalkar N, Ramesh KV. Bone cement implantation syndrome: a rare catastrophe. *Anesth Essays Res* 2011;5:240–2.
- Kapoor B, Datir SP, Davis B, *et al.* Femoral cement pressurization in hip arthroplasty: a laboratory comparison of three techniques. *Acta Orthop Scand* 2004;75:708–12.
- Khanna G, Cernovsky J. Bone cement and the implications for anaesthesia. *Contin Educ Anaesth Crit Care Pain* 2012.
- Govil P, Kakar PN, Arora D, *et al.* Bone cement implantation syndrome: a report of four cases. *Indian J Anaesth* 2009;53:214.
- Murphy P, Edelist G, Byrick RJ, *et al.* Relationship of fat embolism to haemodynamic and echocardiographic changes during cemented arthroplasty. *Can J Anaesth* 1997;44:1293–300.
- Soleimanha M, Sedighinejad A, Haghighi M, *et al.* Hemodynamic and arterial blood gas parameters during cemented hip hemiarthroplasty in elderly patients. *Arch Bone Jt Surg* 2014;2:163–7.
- Griffiths R, White SM, Moppett IK, *et al.* Safety guideline: reducing the risk from cemented hemiarthroplasty for hip fracture 2015: association of anaesthetists of great Britain and Ireland British orthopaedic association British geriatric society. *Anaesthesia* 2015;70:623–6.
- Griffiths R, Parker M. Bone cement implantation syndrome and proximal femoral fracture. *Br J Anaesth* 2015;114:6–7.
- Lawrence JE, Fountain DM, Cundall-Curry DJ, *et al.* Do Patients Taking Warfarin Experience Delays to Theatre, Longer Hospital Stay, and Poorer Survival After Hip Fracture? *Clin Orthop Relat Res* 2017;475:273–9.
- Javad P, Sim Franklin H. Clinical Orthopaedics and Related Research. *Proximal Femoral Replacements with megaprosthesis.*, 2004;420, 169–75.
- Rickman M, Young J, Trompeter A, *et al.* Managing acetabular fractures in the elderly with fixation and primary arthroplasty: aiming for early weightbearing. *Clin Orthop Relat Res* 2014;472:3375–82.
- Smith JR, Halliday R, Aquilina AL, *et al.* Distal femoral fractures: the need to review the standard of care. *Injury* 2015;46:1084–8.
- Parvizi J, Tarity TD, Slenker N, *et al.* Proximal femoral replacement in patients with non-neoplastic conditions. *J Bone Joint Surg Am* 2007;89:1036–43.
- Dean BJ, Matthews JJ, Price A, *et al.* Modular endoprosthetic replacement for failed internal fixation of the proximal femur following trauma. *Int Orthop* 2012;36:731–4.
- Lundh F, Sayed-Noor AS, Brosjö O, *et al.* Megaprosthesis reconstruction for periprosthetic or highly comminuted fractures of the hip and knee. *Eur J Orthop Surg Traumatol* 2014;24:553–7.
- Curtin M, Bryan C, Murphy E, *et al.* Early results of the LPS™ limb preservation system in the management of periprosthetic femoral fractures. *J Orthop* 2017;14:34–7.

Copyright 2017 BMJ Publishing Group. All rights reserved. For permission to reuse any of this content visit <http://group.bmj.com/group/rights-licensing/permissions>.
BMJ Case Report Fellows may re-use this article for personal use and teaching without any further permission.

Become a Fellow of BMJ Case Reports today and you can:

- Submit as many cases as you like
- Enjoy fast sympathetic peer review and rapid publication of accepted articles
- Access all the published articles
- Re-use any of the published material for personal use and teaching without further permission

For information on Institutional Fellowships contact consortiasales@bmjgroup.com

Visit casereports.bmj.com for more articles like this and to become a Fellow