Pressurized Radio-Opaque Dye Integrity Test

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Intraoperative fracture and cortical perforation during total shoulder replacement is a rare but difficult complication, occurring at an incidence of 0.5%-3% according to data in the literature.[1,2,3] Reports of fracture and cortical perforations in the literature largely cite postoperative incidences,[4,5,6] which accounts for 20% of all complication after total shoulder arthroplasty (TSA).[1,2] There are limited accounts that exclusively analyze intraoperative fracture and cortical perforations in primary arthroplasty,[7-10] and even fewer assessing intraoperative fractures and cortical perforations in revision arthroplasty.[7,11] Review of published accounts of both postoperative and intraoperative fractures and cortical perforations concludes that many may have been avoided by better surgical technique,[1,3,12] and subsequently, the associated complications could be avoided. A particularly difficult complication may arise when there is a cortical perforation not easily visualized on intraoperative fluoroscopic imaging. As the majority of revision arthroplasty involves humeral stem cementation, a perforation may allow the egress of cement in its liquid form. The potential harm caused by cement is significant as the exothermic reaction of the methylmethacrylate cement can cause thermal injury to surrounding tissue and, specifically, neurovascular tissue.[13,14]

The radial nerve is most often injured in humeral shaft fractures and perforations, at an incidence of 1.8%-16%.[15] The potential of thermal injury to the nerve by cement extrusion is high as the radial nerve wraps around the humeral shaft as it extends distally to the elbow. The median and ulnar nerves are also in close proximity to the humeral shaft and vulnerable to similar injury.

Here we present the Pressurized Radio-Opaque Dye Integrity Test (PROD-IT) surgical technique, which was developed to reduce complications from cement extrusion caused by unidentified intraoperative fractures or cortical perforations. By utilizing this technique, cement extrusion from the canal, which can cause suboptimal outcomes by damaging both local soft tissue and neurovascular structures, may be avoided.

Surgical Technique

The revision operation is performed with the patient in beach chair position and under general endotracheal anesthesia. The operative arm is draped free in the sterile field to promote total limb mobility. A deltopectoral approach is used. The deltopectoral interval is opened, subdeltoid scar tissue is removed, and the axillary nerve is identified and protected. At this point, the proximal humerus is exposed and the component to be replaced is evaluated. A carbide punch is used to remove the head. An osteotome is employed to remove any soft tissue and bony constraints around the prosthesis. These are sent to pathology for culture and the stem is then removed. The canal is aggressively curetted, all excess cement is removed, and any soft tissue membrane within the canal is entirely resected. The use of ultrasound assisted cement extraction is not employed due to the excessive heat generated and the potential nerve injury this heat might cause.

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After multiple curettings and lavaging of the canal, attention is directed towards evaluating the proximal humerus and subsequent prosthesis insertion. Radio-opaque dye (Omnipaque, GE Healthcare, Shanghai, China) is placed in the canal of the proximal humerus by syringe and viewed under x-ray control (Figure 1). If no dye is seen extravasating initially, the dye syringe is then pressurized with a cement pressurizer in order to promote dye leakage, and the humeral shaft is viewed

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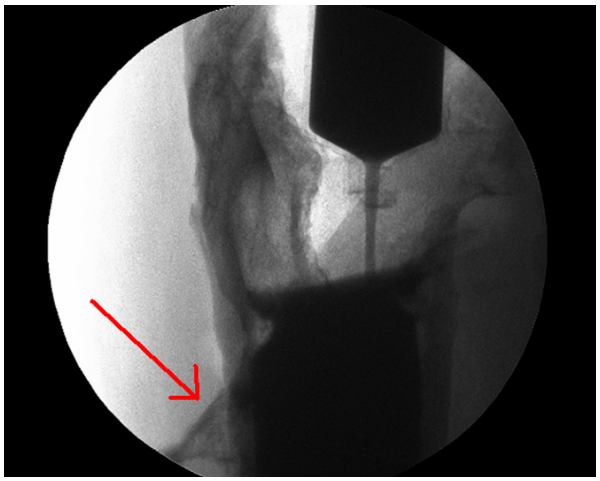

Figure 1. Radio opaque dye being inserted into the humeral canal under x-ray control. Dye can be seen leaking out of the canal in the lower left quadrant of the image (arrow).

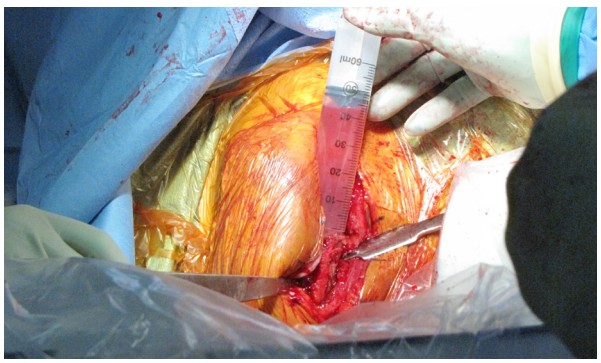

Figure 2. Intraoperative image of a cement pressurizer being placed on the syringe to promote dye extravasation for fracture detection.

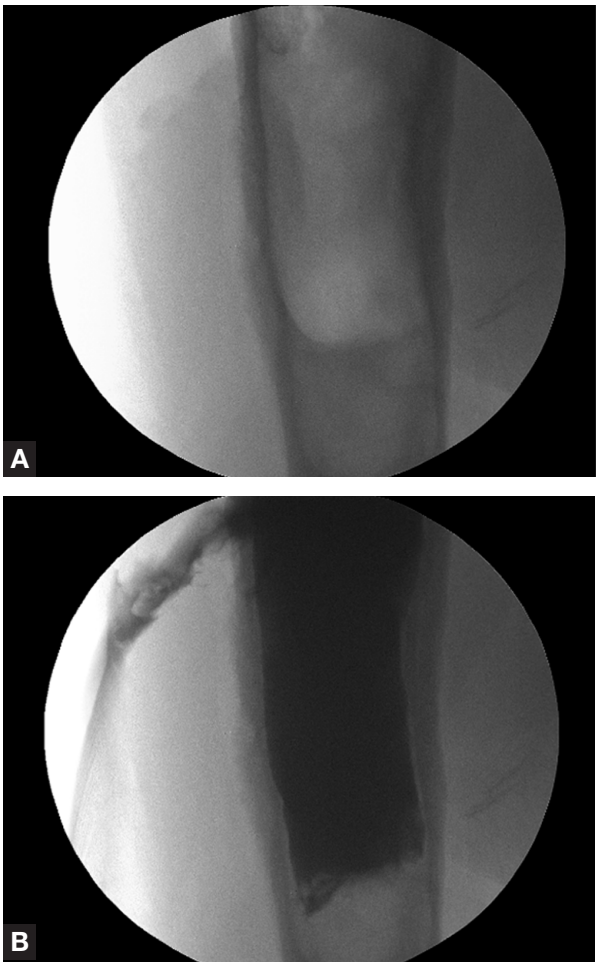

Figure 3. A direct comparison of a humeral canal under plain fluoroscopic visualization (A) and under fluoroscopic visualization with radio opaque dye (B). The fracture can clearly be seen in the canal (B) when dye is applied and seen to leak out of the canal whereas under plain fluoroscopic visualization, no fracture is visualized (A).

under x-ray control a second time (Figure 2). This pressurized method ensures the identification of any minute perforations that are not identifiable by x-ray alone. The operative arm is mobilized and maneuvered under flouroscopic imaging to confirm absence of dye leakage.

At this point, if dye is seen leaking out of the canal, the fracture/perforation site is exposed for direct visualization. Neurovascular structures at risk for cementation exposure are protected by extending the deltopectoral incision distally and packing the area with a wet lap sponge. The humeral canal is then filled with methylmethacrylate cement using antibiotic impregnated cement. It must be noted that any pre-existing infections from previous arthroplasties are not treated in this fashion and undergo two-stage PROSTALAC treatment. During cementation, optimal pressurization is obtained by protecting any existing fracture or cortical perforation sites and all neurovascular structures from cement extrusion. The stem is inserted to the appropriate depth and retroversion. All excess cement is removed as the cement cures. The remainder of the closure is routine and postoperative protocols are made on an individual basis.

Discussion

The potential nerve palsies associated with the pressure or heat damage from cement extrusion can be devastating. There have been 5 cases of humeral canal cement extrusion after TSA managed by the lead author. Of these, 3 have caused radial nerve palsies; 1 transient and 2 permanent requiring tendon transfers. The PROD-IT procedure described above was developed specifically to avoid this neurological complication by identifying cortical perforations that are not visible by x-ray alone.

There have been 6 cases in the literature of radial nerve palsies associated with humeral fracture or perforation in association with prosthetic insertion.[9,14,16,17] Four of these 6 fracture cases occurred during primary shoulder replacement or were discovered shortly after primary replacement.[9,14] Two of these fractures occurred during revision surgeries, one during a total shoulder revision[16] and one after a reverse total shoulder revision.[17] In 2 of the 6 total cases found in the literature,[14,17] the radial nerve was damaged due to cement extrusion at the fracture site.

Nerve injury due to intraoperative fracture or perforation and subsequent cement extrusion during TSA is an uncommon, but devastating occurrence. Even without overt fracture, cement extrusion can still occur in approximately 10% of primary TSA cases because cortical perforations are not identified under direct visualization or under x-ray control.[13] One can only assume this percentage would increase if revisions were taken into account, however, no data exist on this subject as of yet. From the cases performed with the PROD-IT, we have surmised that while fluoroscopy alone may not be adequate to assess subtle cortical perforation sites at the time of revision arthroplasty, combining both dye and fluoroscopy dramatically improves cortical defect detection (Figures 3A and 3B).

Conclusion

The presence of dye extrusion is a clear indicator of fracture and an impetus for protection from cement extrusion. This procedure may be particularly useful in revision arthroplasty cases where the incidence of fracture is raised significantly. The senior author has had no complications stemming from the PROD-IT technique and furthermore, no complications in revision shoulder surgeries from cement extrusion since implementing the PROD-IT technique. Using PROD-IT to assess for dye extrusion before cementation gives the surgeon another tool with which to analyze the fracture site and protect neurovascular structures, which may prevent catastrophic complications.

Authors' Disclosure Statement

The authors report no actual or potential conflict of interest in relation to this article.

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