Potential Operating Room Fire Hazard of Bone Cement

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Abstract

Approximately 600 cases of operating room (OR) fires are reported annually. Despite extensive fire safety education and training, complete elimination of OR fires still has not been achieved. Each fire requires an ignition source, a fuel source, and an oxidizer.

In this case report, we describe the potential fire hazard of bone cement in the OR. A total knee arthroplasty was performed with a standard medial parapatellar arthrotomy. Tourniquet control was used. After bone cement was applied to the prepared tibial surface, the surgeon used an electrocautery device to resect residual lateral meniscus tissue—and started a fire in the operative field. The surgeon suffocated the fire with a dry towel and prevented injury to the patient.

We performed a PubMed search with a cross-reference search for relevant papers and found no case reports outlining bone cement as a potential fire hazard in the OR. To our knowledge, this is the first case report identifying bone cement as a fire hazard.

OR fires related to bone cement can be eliminated by correctly assessing the setting time of the cement and avoiding application sites during electrocautery.

Approximately 600 cases of operating room (OR) fires are reported annually.[1] The incidence of OR fires in the United States equals that of wrong-site surgeries, and 20% of cases have associated morbidity.[1,2] The estimated mortality rate is 1 to 2 cases per year.[3-5] The most commonly involved anatomical regions are the airway (33%) and the face (28%).[4] Most surgical fires are reported in anesthetized patients with open oxygen delivery systems during head, neck, and upper chest surgeries; electrosurgical instruments are the ignition source in 90% of these cases.[6] Despite extensive fire safety education and training, complete elimination of OR fires still has not been achieved.

Each fire requires an ignition source, a fuel source, and an oxidizer.[7] In the OR, the 2 most common oxidizers are oxygen and nitrous oxide. Head and neck surgeries have a high concentration of these gases near the working field and therefore a higher risk and incidence of fires. Furthermore, surgical drapes and equipment (eg, closed or semi-closed breathing systems, masks) may potentiate this risk by reducing ventilation in areas where gases can accumulate and ignite. Ignition sources provide the energy that starts fires; common sources are electrocautery, lasers, fiber-optic light cords, drills/burrs, and defibrillator paddles. Fires are propagated by fuel sources, which encompass any flammable material, including tracheal tubes, sponges, alcohol-based solutions, hair, gastrointestinal tract gases, gloves, and packaging materials.[8] Of note, alcohol-based skin-preparation agents emit flammable vapors that can ignite.[9-14] Before draping or exposure to an ignition source, chlorhexidine gluconate-based preparations must be allowed to dry for at least 3 minutes after application to hairless skin and up to 1 hour after application to hair.[15] Inadequate drying poses a risk of fire.[10]

We present the case of an OR fire ignited by electrocautery near freshly applied bone cement. No patient information is disclosed in this report.

Case Report

Our patient was evaluated in clinic and scheduled for total knee arthroplasty (TKA). All preoperative

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Table. **Preparation Times for Bone Cements Commonly Used in Operating Rooms (65°F)**

	Time, min				
Medium/High-Viscosity Cement	**Mix**	**Pickup**	**Work**	**Final Set**	**Overall Set**
DePuy Synthes 3	0.8	2.7	5.5	2.5	11.5
SmartSet GMV Endurance	0.8	2.7	8.0	2.5	14.0
SmartSet MV Endurance	0.8	2.7	8.0	2.5	14.0
Simplex P	0.8	2.3	6.5	4.7	14.3
Palacos R40	0.8	0.6	5.0	6.1	12.5
SmartSet GHV	0.8	0.5	8.0	3.2	12.5
SmartSet HV	0.8	0.5	8.0	3.2	12.5
DePuy Synthes 1 Gentamicin	0.8	1.0	6.2	3.0	11.0
DePuy Synthes 1	0.8	1.0	6.5	2.7	11.0
DePuy Synthes 2	0.8	0.3	3.0	2.4	6.5

safety checklists and time-out procedures were followed and documented at the start of surgery. The TKA was performed with a standard medial patellar arthrotomy. Tourniquet control was used after Esmarch exsanguination. The surgery proceeded uneventfully until just after the bone cement was applied to the tibial surface. The surgeon was using a Bovie to resect residual lateral meniscus tissue when a fire instantaneously erupted within the joint space. Fortunately, the surgeon quickly suffocated the fire with a dry towel. The ignited bone cement was removed, and the patient was examined. There was no injury to surrounding tissue or joint space. Surgery was resumed with application of new bone cement to the tibial surface. The artificial joint was then successfully implanted and the case completed without further incident. The patient was discharged from the hospital and followed up as an outpatient without any postoperative complications.

Discussion

Bone cement, which is commonly used in artificial joint anchoring, craniofacial reconstruction, and vertebroplasty, has liquid and powder components. The liquid monomer methyl methacrylate (MMA) is colorless and flammable and has a distinct odor.[16] Exposure to heat or light can prematurely polymerize MMA, requiring the addition of hydroquinone to inhibit the reaction.[16] The powder polymethylmethacrylate affords excellent structural support, radiopacity, and facility of use.[17] Dibenzoyl peroxide and N,N-dimethyl-p-toluidine are added to the powder to facilitate the polymerization reaction at room temperature (ie, cold curing of cement). Premature application of unpolymerized cement increases the risk of fire from the volatile liquid component.

In the OR, bone cement is prepared by mixing together its powder and liquid components.[18] The reaction is exothermic polymerization. The liquid is highly volatile and flammable in both liquid and vapor states.[16,19] The vapors are denser than air and can concentrate in poorly ventilated areas. The OR and the application site must be adequately ventilated to eliminate any pockets of vapor accumulation.[16] A vacuum mixer can be used to minimize fume exposure, enhance cement strength, and reduce fire risk while combining the 2 components.

MMA's *flash point*, the temperature at which the fumes could ignite in the presence of an ignition source, is 10.5°C. The *auto-ignition point*, the temperature at which MMA spontaneously combusts, is 421°C.[20] The OR is usually warmer than the flash point temperature, but the electrocautery tip can generate up to 1200°C of heat.[21] Therefore, bone cement is a potential fire hazard, and use of Bovies or other ignition sources in its vicinity must be avoided.

The **Table** lists the recommended times for preparing various bone cement products.[22,23] *Mix time* is the time needed to combine the liquid and powder into a homogenous putty. *Pickup time* is the minimum time required for putty to increase in viscosity, and no longer adhere to fingers. *Work time* is the time needed for the cement to be applied to the target anatomy and for subsequent implantation. *Final set time* is the time needed for final solidification and shaping of the applied cement. The risk of vapor ignition by a Bovie is highest during pickup time.[16]

The flammability of bone cement mandates that,

before surgery, the OR staff familiarize themselves with the work times of the cement they intend to use. In addition, the viscosity of the cement should be tested (with a powder-free latex gloved finger) before application.[23]

In the present case, resection of excess lateral meniscus tissue was attempted after the cement was applied. We recommend removing all residual tissue before applying wet cement. Blunt dissection may substitute for cautery when needed. Freer elevators and cement remover curettes may also be safely used. Use of an inactive Bovie for dissection should be avoided to prevent accidental activation and ignition. The risk of fire with bone cement decreases with appropriate use and with the OR staff's increased experience.

For OR fires, the standard guidelines for rapid containment and safety apply. These guidelines are detailed by the American Society of Anesthesiologists.[8] Briefly, delivery of all airway gases to the patient is discontinued. Any burning material is removed and extinguished by the OR staff.[1] Carbon dioxide fire extinguishers are used to put out any patient fires and minimize the risk of thermal injury. (Water-mist fire extinguishers can contaminate surgical wounds and present an electric shock hazard with surgical devices and should be avoided.[24]) If a fire occurs in a patient's airway, the tracheal tube is removed, and airway patency is maintained with use of other invasive or noninvasive techniques. Often, noninvasive positive pressure ventilation without supplemental oxygen is used until the fire is controlled and the patient is safe. Once the patient fire is controlled, ventilation is restarted, and the patient is evacuated from the OR and away from any other hazards, as required. Last, the patient is physically examined for any injuries and treated.[24] Specific to TKA, the procedure is resumed after removal of all bone cement, inspection of the operative site, and treatment of any fire-related injuries.

We have reported the case of an OR fire during TKA. Appropriate selection and use of bone cement products, proper assessment of set time, and avoidance of electrocautery near cement application sites may dramatically reduce associated fire risks.

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