Bone Cement Implantation Syndrome During Spinal Surgery Requiring Cardiac Surgery

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During a posterior segmental spinal fusion procedure, a 71-year-old woman developed cardiac and pulmonary embolism characterized by nonsustained ventricular tachycardia during cement injection, rapid and severe hypoxemia, and hemodynamic instability. Management included exploratory cardiotomy under cardiopulmonary bypass and removal of the emboli from the pulmonary vessels. Postoperative recovery was successful, and the patient was discharged without sequelae. We discuss the pathophysiology of bone cement implantation syndrome during spinal fusion, possible causative factors, and treatment alternatives. (A&A Case Reports 2013;1:82–5)

Polymethylmethacrylate (PMMA) is acrylic cement commonly used to provide increased fixation of orthopedic hardware. Complications of its use are uncommon but include bone cement leakage into the pervertebral venous system from which it may migrate to the right heart and the pulmonary circulation resulting in bone cement implantation syndrome (BCIS). IRB permission was obtained before publishing this report.

CASE DESCRIPTION

A 71-year-old obese (body mass index = 35.41 kg·m⁻²) woman with hepatitis C underwent posterior segmental fusion from D12 to L2 with titanium screws under general anesthesia to repair a compression fracture at the first vertebra after a car accident. Because bone was osteoporotic, low-viscosity, acrylic, radiopaque osseous cement (Spine Fix®, Teknimed, Vic en Bigorre, France) was used to assist screw fixation. During cement injection through a pedicle, the neurosurgeon observed cement entering the pervertebral vessels on fluoroscopy (Fig. 1) followed rapidly by premature vertebral contractions that were short lived. However, at the end of the procedure, while moving the patient from prone to supine position, hemodynamic instability including runs of nonsustained ventricular tachycardia requiring IV amiodarone and decreasing hemoglobin oxygen desaturation occurred. Because of suspicion of a PMMA embolism, a computed tomography (CT) was performed and confirmed this diagnosis. (Figs. 2 and 3) The patient underwent cardiac surgery to remove the emboli under cardiopulmonary bypass (CPB).

Anesthesia was maintained during surgery with propofol infusion 4 mg·kg⁻¹·h⁻¹, remifentanil 0.1 to 0.5 µg·kg⁻¹·min⁻¹, and intermittent doses of cisatracurium. Intraoperative transesophageal echocardiography before instituting CPB demonstrated a dilated right ventricle and a tricuspid annular plane systolic excursion of approximately 14 mm. Her hemodynamic variables were: cardiac index 1.4 L·min⁻¹·m⁻² and stroke volume variation 25%, treated with fluid bolus and epinephrine 0.06 µg·kg⁻¹·min⁻¹ resulting in cardiac index and arterial blood pressure increasing to normal. After the onset of CPB, multiple emboli were removed from both pulmonary arteries (Fig. 3). Postoperatively, persistent hypoxemia required gradual separation from mechanical ventilation, and the trachea was extubated on the 6th postoperative day. After discharge from the intensive care unit on the 11th postoperative day, she had an episode of supraventricular tachycardia treated with amiodarone and was discharged from the hospital 16 days after surgery without oxygen but receiving acenocoumarol for 6 months.

DISCUSSION

Transpedicular cement injection using PMMA to assist fixation of pedicular screws is a common practice when the bone is osteoporotic. Percutaneous injection of bone cement may increase intramedullary pressure, and, thereby, force both marrow contents and cement into the paravertebral venous circulation. The incidence of BCIS varies with the procedure: 0.8% after pedicle screw augmentation, close to 0.9% after spinal fusions,¹ and from 3% to 23% after vertebroplasty and kyphoplasty²; however, recent studies,³ using routine CT, suggest that the incidence after vertebroplasty and kyphoplasty may be as great as 23% to 26%. The intraoperative incidence of death during cemented vertebroplasty or transpedicular screw fixation is unknown, but 1 study has shown an incidence of 0.09% deaths because of cardiorespiratory problems during the introduction of cement in patients undergoing total hip arthroplasty.⁴

Cement accesses the venous system because vertebrae are highly vascularized; moreover, osteoporosis destroys the vertebral body and permits direct shunting of cement fragments to the venous system. Several risk factors have been implicated in the genesis of the BCIS: (a) patient-related risk factors including increased age, preexisting pulmonary hypertension, bony metastases, and fractures⁵; (b) factors related to the procedure including insufficient polymerization of the PMMA at the time of

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the injection, high intramedullary pressure, malposition of the needle, overfilling the bone, multilevel application, and lack or misuse of real-time fluoroscopy. Maneuvers that may prevent embolization include injecting the cement with an appropriate viscosity (paste-like consistency) and in bursts rather than continuously, using high-resolution c-arm fluoroscopy and radiopaque cement, injecting contrast to identify a shunt from the needle to the venous system and closing it with gelfoam.

The physiological consequences of embolization are considered the result of both a mechanical effect and mediator release (PMMA microparticles activate the inflammatory anaphylactic cascade, and endothelial permeability is altered with activation of the complement system and liberation of histamine) provoking increased pulmonary vascular tone and shunting of blood that is the most likely cause of hypoxemia and hypocapnia.5,7 The effects on the pulmonary vasculature are usually transient but may be persistent and sometimes manifest as late sequelae.6

BCIS has a wide spectrum of severity, and the degree of embolization correlates poorly with the extent of hypotension or hypoxemia; most patients, even with pulmonary emboli detected by chest radiographs, remain asymptomatic. However, some lethal consequences, including fatal pulmonary embolism, paradoxical cerebral embolism, cardiac perforation, renal embolism, ventricular tachycardia, and acute respiratory distress syndrome have been reported. When embolism is suspected, the diagnosis can be made by transesophageal echocardiography, which is inexpensive and noninvasive, but CT is the most effective method to confirm diagnosis.

The optimal treatment strategy for pulmonary cement embolism is not clear, although the following decision tree has been suggested.6 Clinical follow-up in the presence of asymptomatic peripheral embolization, anticoagulation with heparin followed by coumadin for 6 months to avoid additional thrombosis (until the foreign body is endothelialized in cases of symptomatic peripheral embolization or in central asymptomatic embolization); however, in the presence of hemodynamic instability (severe respiratory and/or cardiac failure), a percutaneous or surgical removal procedure should be considered. While embolism is rather common in orthopedic surgery, the need to use CPB, as in our patient, is rare, and publications describing the use of cardiac surgery for the removal of acrylic cement are scarce.6,10,12,14

Of particular concern is in patients with a patent foramen ovale (PFO), a clinical entity that is present in approximately 1 of every 4 adults. In this situation, paradoxical embolism can occur spontaneously or secondarily due to the right atrial pressure increase (caused by pulmonary hypertension or accompanying high inflating pressures) that can transiently reverse the normal left-to-right pressure gradient forcing the opening of the PFO. Proof of the prognostic importance is the tripled stroke risk of patients with pulmonary embolism in the presence of a PFO.15 Because of this frequent prevalence of PFO, one might think that preoperative detection and percutaneous closure could decrease the incidence of paradoxical embolism. The screening of a PFO by echocardiography in patients undergoing neurosurgery in the sitting position has been recommended by some authors; however, there is no well-established recommendation for the systematic use of echocardiography for detecting PFO in patients with fractures. In terms of preoperative risk assessment, the most important initial consideration is whether the patient has a history of embolic events because a history of cryptogenic stroke is an indication for preoperative transesophageal echocardiography.17 Patients with a known PFO >4 mm, atrial septal aneurysm, or spontaneous right-to-left passage of bubble contrast at echocardiography also have been shown to be at significantly higher risk for paradoxical embolism. Two strategies (antithrombotic medications or percutaneous closure) have been used for secondary prevention of embolism in patients with PFO; but, the most effective strategy for the prevention of stroke recurrence in such patients is uncertain, although some experts recommend...
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closure of the PFO to prevent future embolic events before undergoing major orthopedic procedures. However, the results of prospective studies that have attempted to solve the dilemma about which is the most appropriate therapy in preventing stroke recurrence (Established Current Standard of Care Treatment [RESPECT], Clinical Trial Comparing Percutaneous Closure of the Patent Foramen Ovale Using the Amplatzer PFO Occluder with Medical Treatment in Patients with Cryptogenic Embolism [PC] and Evaluation of the STARFlex Septal Closure System in Patients with a Stroke and/or Transient Ischemic Attack Due to Presumed Paradoxical Embolism through a Patent Foramen Ovale [CLOSURE I]) do not show a significantly lower rate of the primary end points with closure than with medical therapy in the primary intention-to-treat analysis. In addition, percutaneous closure of a PFO is not harmless (with adverse events occurred in 21 of 499 patients [4.2%] in the closure group in the RESPECT trial). For this reason, there is great uncertainty about which is the best prophylactic measure against embolism in patients with a PFO, and it is not possible to make any specific recommendations with a high level of evidence. However, these trials were not performed in patients anticipating surgery. Because of the increased risk of embolism in orthopedic surgery (especially when acrylic cement is required), a prospective study is needed to define the future role of percutaneous closure of PFOs in this population subgroup.

REFERENCES

Figure 2. a, Computed tomography scans demonstrated linear radiodense deposits suspicious for bone cement in the right pulmonary artery, lower lobe pulmonary artery, and arterial segmental branches (A). b, High-density material within the right ventricle (B).

Figure 3. a, Arteriotomy in the right pulmonary artery showed a filiform foreign body extended to the lobar branches. b, Large fragment removed from left pulmonary artery. The fragment could be the large fragment seen during the computed tomography scan in the right ventricle, which was not found in the right chambers during surgical exploration (A). Thin, linear cement particles and a larger fragment discovered within the right pulmonary artery extended toward the lobar branches (B).