Aspects of Cementation in Shoulder Hemiarthroplasty after Complex Fracture of the Proximal Humerus

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The first uses of the polymers at the articular level were: joint components, cement fixation of prosthetic components at the bone, and sutures of tendons and ligaments. Since 1970, when polymethyl methacrylate (PMMA) was introduced, bone cement is the choice of choice to fix the prosthetic implant to bone. The cementation of the implant components is a commonly used procedure for hip, knee and shoulder arthroplasty: the femoral stem and the acetabular cup (in the case of total hip arthroplasty), the femoral and tibial components (in the case of total knee arthroplasty), the humeral stem (in hemiarthroplasty, total arthroplasty: anatomical or arthroplasty with inverse shoulder prosthesis) The objectives of this study are to establish the optimal indication of the cementing process, to evaluate and compare the results of cemented hemiarthroplasty, the real benefit from the immediate postoperative functional recovery program, for elderly patients with a diminished bone stock with complex fractures of proximal humerus. The success of the surgical treatment for complex fractures of proximal humerus depends to a large extent on establishing a correct diagnosis, an optimal surgical indication, a thorough preoperative planning, an optimal implant, a periarticular soft tissue reconstruction, and an effective postoperative recovery program.

Keywords: bone cement, 3D computed tomography reconstruction, proximal humerus fracture, cemented hemiartroplasty

The cementation of the implant components is a commonly used procedure for hip, knee and shoulder arthroplasty [1]: the femoral stem and the acetabular cup (in the case of total hip arthroplasty), the femoral and tibial components (in the case of total knee arthroplasty), the humeral stem (in hemiarthroplasty, total arthroplasty: anatomical or arthroplasty with inverse shoulder prosthesis) [3-6].

Most commonly, the hemiarthroplasty will be performed by 4-part proximal humerus fractures according to Neer's classification (humeral head fragment, large tuberosity, small tuberosity and humeral diaphysis, displaced more than 1 cm and angulated over 45 degrees) [6]. In the evaluation of the movement and angulation of the fragments a computed tomography of the shoulder and a three-dimensional reconstruction of the shoulder are performed [7,10].

The first uses of the polymers at the articular level were: joint components, cement fixation of prosthetic components at the bone, and sutures of tendons and ligaments. Since 1970, when polymethyl methacrylate (PMMA) was introduced, bone cement is the choice of choice to fix the prosthetic implant to bone [8,9].

There are several types of bone cement, having the same component, methyl polymethacrylate. Although they are different in composition and their properties differ insignificantly. At present, there is no evidence of differences in the results obtained after the use of bone cement, even after application using inappropriate surgical technique [2,7].

The success of the surgical treatment for complex fractures of proximal humerus depends to a large extent on establishing a correct diagnosis, an optimal surgical indication, a thorough preoperative planning, an optimal implant, a periarticular soft tissue reconstruction, and an effective postoperative recovery program [11-13].

Addition of antibiotic powders to the bone cement composition results in an increase in porosity after action and absorption of the drug. After removal of the antibiotic, pores and microstripes occur in the cement, being a primary surface process. Adding antibiotics in significant amounts resulted in a decrease in resistance following application of compressive, traction and flexion forces. This is why the concentration of antibiotic powders in the bone cement composition is measured [14,15].

Experimental part

The objectives of this study are to establish the optimal indication of the cementing process, to evaluate and compare the results of cemented hemiarthroplasty, the real benefit from the immediate postoperative functional recovery program, for elderly patients with a diminished bone stock with complex fractures of proximal humerus.

The bone cement presentation form is a kit with 2 components: one 40g powder vial and one ampoule with 20mL of liquid. Generally, the solid component exhibits 10% $BaSO_4$ and the remaining powder of PMMA or PMMA-poly (styrene) copolymer [17,20].

From a group of 50 patients with proximal humerus fractures treated in the Clinical of Orthopedics and Traumatology of the Central Military Emergency Hospital *Carol Davila* Bucharest between January 2016 and December 2017, through different treatment methods (orthopedic, surgically by various techniques of osteosynthesis, hemiarthroplasty and total arthroplasty), we selected 7 cases, 73-88 year old patients, with complex closed proximal humeral proximal fractures with significant displacement, diminished bone stock, with the indication of hemiarthroplasty.

The surgical indication was established after analyzing the computed tomography sections of the shoulder (fig. 1-4) and the three-dimensional reconstruction of computed

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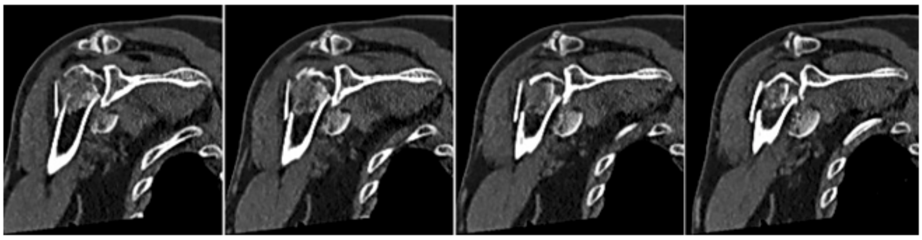

Fig. 1-4. Coronal computed tomography sections of the shoulder (73 years old male)

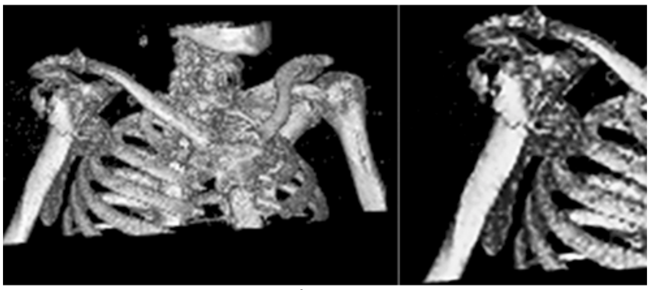

Fig. 5,6. 3D reconstruction of computed tomography (73 years old male)

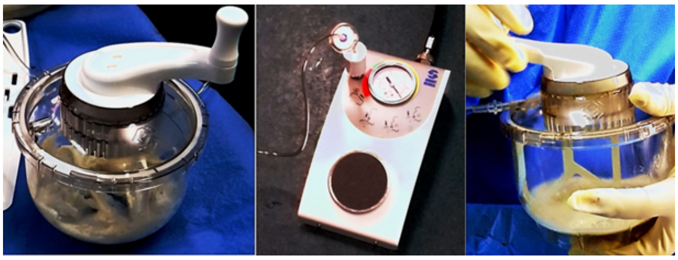

Fig. 7,8,9. Mixing the cement components into the negative pressure vessel

tomographies (fig. 5,6), the degree of fragmentation and the fracture pattern, with secondary damage to the vascularization, excluding any type of osteosynthesis.

Surgery was performed under general anesthesia, the patient being positioned in a beach-chair position. An delto-pectoral approach was practiced. It has been chosen to cement the humeral stem for a solid fixation. The reconstruction of the tuberosities and the restoration of the rotator cuff is necessary in case of shoulder hemiarthroplasty.

Mixing the cement components (figs. 7-9) is done in about 2-3 minutes at a temperature of 23-25 degrees Celsius and a relative humidity of 65%. After mixing, the paste will be loaded into a pressure gun or a syringe to be applied [19]. The application period is when the paste reaches half the maximum temperature, and takes 8-10 min. The exothermic reaction during polymerization produces 12-14 kcal / 100g of bone cement[20]. Significant quantities of cement (about 50-60 g) can reach temperatures of 70-80 degrees Celsius, but in vivo, the capacity of the prosthetic components to absorb heat [21], as well as the adjacent circulation, the local temperature does not exceed 39-42 degrees Celsius, for a short time, to a thickness of up to 5 mm of cement [22] (figs. 7-9).

When mixing the components, an additional polymerization process forms long chain polymers that interpenetrate the polymerized microspheres, forming a paste [2]. Noteworthy is that the newly formed polymer chains are generally linear and not cross-linked [7,14].

Results and discussions

In order to obtain excellent results after the surgical treatment of complex prosthetic humerus fractures involving shoulder hemiarthroplasty, is mandatory to limit the dissection of soft periarticular tissues [3, 11, 16], to repair tuberosity and to restore the rotator cuff (fig. 10,11).

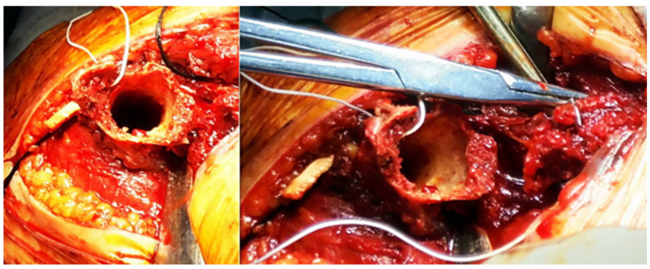

Fig. 10,11. Intraoperative hemiarthroplasty aspect - humeral diaphysis; crossing the transosseous wires in order to restore the position of detached tuberosities

The fixation of the humeral stem after restoration of the appropriate position by cementation (figs. 12-16) is necessary in patients with a deficient bone stock with proximal humerus fractures, with a low failure rate in terms of prosthesis displacement and the need for a new intervention, revision surgery [6,16].

Fig. 12,13. Intraoperative hemiarthroplasty aspect - the cementing stage

Fig. 14,15,16. Intraoperative hemiarthroplasty aspect - the fixation of the humeral stem

The use of antibiotic cement is an additional method in prophylaxis of osteoarticular infections [2,13]. A correct positioning of the stem will maintain the anatomical and biomechanical proportions of the shoulder joint [3,6] .

Bone cements are polymers used in orthopedic surgery to fix prosthetic components or damaged areas of bones [8,24]. The properties of these polymers to transfer and distribute static loads and dynamic stresses from the implant interface to bone tissue are other strengths that favor their therapeutic indication [22].

The forces exerted on the components of the cemented prosthesis may cause the cement to crack, which may lead to decimation over time, with loss of uniform distribution of bone loading forces and thus compromise the implant[20]. In these cases, revision surgery is required to reposition the components or to replace them [1,2,23].

Bone cement was designed not to modify its volume to prevent secondary movement of the articular implant components. Bone cement reduces its volume by 0.5-1%

during application and fixation of prosthetic components, and will retain water and lipids within the first 30 days, increasing the volume by 1-2% [6] .

The presence of bone porosity and other force surges at the time of cement application are other considerations that lead to the low resistance of methyl poly-methylacrylate over time. Due to this, fatigue fractures are one of the main causes of degradation of assembly and decay [5].

The reduction in volume is correlated with the exothermic reaction from the time of mixing the cement components, but also with the presence of porosity in the structure of the paste obtained. If cement is obtained by mixing with a spatula in a vessel, the porosity will be 1-10%, depending on technique and experience. It has been noticed that mixing at a moderate speed results in a cement with a lower porosity. Several techniques such as centrifugation, vacuum mixing have reduced porosity, but the benefits of this have not been highlighted [6].

To improve the mechanical properties of bone cement, the researchers tracked the structure of the methicillin polymethacrylate incorporating various fibers such as carbon, steel, Kevlar, UHMW-PE, and titanium at the matrix level [2]. These compounds have improved mechanical properties, increased resistance to repeated loading to avoid fractures, but the incompatibility between these fibers and methyl polymethylacrylate has resulted in poor fixation of prosthetic implants [1].

A role in the disorganization of cement is represented by the radiopaque substance added to the cement components for the radiological examination of the target segment [18,19]. These substances, such as barium salts and metal oxides, reduce the mechanical properties of cement. Conglomerates formed due to higher density and polarity, lead to concentration of stress forces and thus reduce elasticity, strength and increase the risk of fracture [17,23].

Conclusions

Also, fractured bone quality, osteoporosis, advanced age of the patient, preservation of humeral head vascularity are essential conditions to be considered for choice of hemiarthroplasty over reduction and plate osteosynthesis and blocked screws [3,6]. Typically, this type of complex third proximal humerus fracture with 3 or 4 parts is accompanied by the dislocation of the remaining humeral head fragment with implicit vascularization [4,5].

The cemented fixation of the components allows a firm, solid holding and uniform distribution of loading forces on the remaining bone following osteotomy [1,2].

The postoperative recovery program, involving passive mobilization of the shoulder joint, has been improved, achieving superior results due to its early onset, the fixation of the components by cementation providing remarkable stability.

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