Technical Note

Harvest, Transport, and Storage of Fresh Humeral Head Osteochondral Allograft: Step-by-Step Protocol

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Abstract: Articular cartilage defects are not common in the glenohumeral joint and are mostly found in patients after shoulder trauma, in patients with recurrent instability, or in patients who underwent previous surgical treatment. Articular cartilage defects lead to pain and loss of motion, consequently causing shoulder function impairment and reducing quality of life. In young patients, the use of osteochondral allografts for the treatment of humeral head defects may avoid well-known complications of shoulder arthroplasty. The goal of this Technical Note is to describe a step-by-step protocol for the harvesting, transport, and preservation of fresh humeral head osteochondral tissue for use in allograft transplantation.

Articular cartilage defects are relatively common in the glenohumeral joint, with rates of around 5% to 17% according to some authors, and are mostly found in patients after shoulder trauma, in patients with recurrent instability, or in patients who underwent previous surgical treatment. Hence, diagnosis can be difficult, and defects are frequently found during arthroscopic or open surgical treatment of other diseases. Focal cartilage defects lead to pain and loss of motion, consequently causing shoulder function impairment and reducing quality of life. Although arthroplasty and humeral head resurfacing techniques are associated with improvement in pain and function, these techniques are more suitable for older and low-demand patients. On the other hand, in younger patients, autologous chondrocyte implantation, osteochondral autograft, and osteochondral allograft are described as treatment options owing to the poorer outcomes of arthroplasty described in this population. Besides, humeral head reconstruction with osteochondral allografts can improve shoulder range of movement, leading to better functional outcome scores and resulting in lower subsequent dislocation rates.

Most literature regarding allografts involves the use of articular cartilage specimens from the knee joint. However, this type of allograft does not seem suitable for reconstruction of the articular surface of the humeral head because of differences in both cartilage thickness and curvature. Moreover, there is no consensus in the literature regarding the standardization of a protocol for the harvest, transport, and preservation of humeral osteochondral allografts in tissue banks. So, the goal of this Technical Note is to describe a step-by-step protocol for the harvesting, transport, and preservation of fresh humeral head osteochondral tissue for use in allograft transplantation (Video 1).

Surgical Technique

Tissue Harvesting and Transport

After positive notification by the state’s transplant central registry of a viable corpse donor (Table 1), a team (5 doctors and 3 nurses) is dispatched to the
 quests made by the orthopaedic division to the tissue bank.

Table 1. Exclusion Criteria for Organ Donation

| Group | Criteria |
|-------|----------|
| 1     | Diseases diagnosed or suspected before donation as follows: major burns, malignant neoplasms with potential to metastasize, active tuberculosis, sexually transmitted diseases, malaria, acquired immunodeficiency syndrome, or systemic bacterial or fungal disease diagnosed during hospitalization and sepsis. |
| 2     | Behavior or situations in 12 mo preceding donation as follows: contamination by toxic substance; injectable drug use that is illicit or without therapeutic indication; tattoos; acupuncture retouching; definitive makeup and body adornments with no possible evaluation of needle sterilization; dialysis or sexual relations with patients undergoing dialysis; paid sexual relations; multiple sexual partners; male individuals with sexual relations with other male individuals or their female partners; sexual relations with individuals with positive results for HIV, hepatitis B or C, or other blood-transmitted diseases; or detention for >24 h in prison or custodial facility. |
| 3     | Unable to undergo donation considering the minimal interval required for safety between vaccination date and donation date. Minimum 48-h interval; brucellosis, cheola, pertussis cough, diphtheria, typhoid fever (injectable), *Haemophilus influenzae*, hepatitis A, recombinant hepatitis B, leptospirosis, meningitis, bubonic plague, poliomyelitis (Salk), and tetanus. Minimum 3-wk interval: BCG, mumps, yellow fever, oral typhoid fever, oral poliomyelitis (Sabin), and measles. Minimum 4-wk interval: rubella, varicella, influenza, prophylactic antirabies, and antitetanic serum. Minimum 1-yr interval: antirabies after animal exposure, plasma-derived hepatitis B, passive immunotherapy, and vaccines in experimental step. |
| 4     | Diseases or therapeutics that must be controlled and justified in medical records regarding donor exclusion or not: immunosuppressant treatment; growth hormone treatment; prior organ and tissue transplant at <12 mo, except when source is controlled; chemotherapy or radiotherapy treatment, except for benign lesions; unknown result of surgery; prior biopsy because of cutaneous lesion; or prior transfusion of blood or its derivates at <12 mo, except when source is controlled. |
| 5     | Specific exclusion criteria under tissue bank criteria: Segment exclusion: trauma with abrasions and major local hematoma or superficial cutaneous infections. Whole-limb exclusion: deep venous puncture with infection signs. |

NOTE. The exclusion criteria are divided into 5 groups according to national regulations. If the corpse donor does not fulfill any of the criteria, serologic testing is performed and then harvest begins.

BCG, bacillus Calmette-Guérin vaccine; HIV, human immunodeficiency virus.

Chlorhexidine is used to perform asepsis, and alcoholic chlorhexidine is used for antisepsis. The surgical drapes are then placed.

The surgical technique for harvesting osteochondral tissue from the proximal humerus consists of performing the deltopectoral approach, using the coracoid process and the lateral surface of the humerus as anatomic references (Fig 1A). After skin incision, the deltoid and pectoralis major muscles are shifted laterally and medially, respectively. To improve visualization, a pectoralis major tenotomy is performed, and the deltoid muscle is detached from the lateral and posterior surfaces of the humerus with the aid of a surgical remover; 24-cm Hohmann surgical retractors may also be used to facilitate exposure.

Tenotomy of the subscapularis is performed at its insertion on the humeral lesser tuberosity. It is extremely important to avoid damaging the articular cartilage in this step. External rotation of the upper limb helps decrease this risk and increases surgical exposure. In this step, the axillary vessels and nerve, which pass inferior to the subscapularis muscle, are sectioned. The teres major tendon is also detached from the crest of the humeral lesser tuberosity. The rotator interval is opened, with tenotomy of the long head of the biceps, in the region of the supraglenoid tubercle. To facilitate exposure, tenotomy of the supraspinatus, infraspinatus, and teres minor tendons is performed under internal rotation of the upper limb, with extreme care taken not
to damage the humeral articular cartilage. At the posterior humeral surface, the origin of the triceps muscle lateral head is sectioned.

A reciprocating saw and a bone clamp are used in the resection of the proximal humeral extremity, which is performed 10 to 15 cm below the humeral greater tuberosity (Fig 1B). After osteotomy with the aid of a clamp, proximal humerus piece elevation and opening of the whole posterior and inferior capsule are performed, with removal of remaining muscle until complete release of the piece. Two tissue samples are taken at this time and stored in a container at a controlled temperature (4°C) for microbiological analysis (fungi and aerobic bacteria) in the tissue bank.

The humeral proximal extremity is placed in 0.9% saline solution and stored in triple sterile plastic packaging, which is appropriately sealed and contains the corpse donor identification number and initials, tissue identification with laterality, and harvesting date. Packages are stored in a container at a controlled temperature (4°C) and sent for processing at the tissue bank (Fig 2). The container inner temperature must be registered during tissue placement and removal for storage in the tissue bank refrigerator at 4°C. After removal of the humeral proximal extremity, the corpse donor body is recomposed, resembling natural anatomy, using polyvinyl chloride pipes or broomsticks, which are fixed to the glenoid with crossed Kirschner wires and covered with compresses before wound closure.

### Tissue Reception and Storage

On arrival in the tissue bank facility, corpse donor data (name, harvesting date, and amount and type of tissue harvested) are registered. All legal documentation must be checked at this moment. When tissue is
removed from the transport container, the temperature and weight are measured and visual analysis of the packages is performed; these data are registered on the identification tag, which is sealed with the package. The tissue is then stored in the “tissue-reception refrigerator” at 4°C until processing (Fig 3). The samples collected during harvest are sent for microbiological analysis.

In the next step, the proximal humeral extremity undergoes radiologic screening. The tissue package is transported to the radiology unit in the same container at a controlled temperature. After radiographs are obtained, the tissue is transported back to the tissue bank and is stored in the tissue-reception refrigerator. The radiographic report is evaluated by the physician responsible for the tissue bank, who defines whether the tissue is adequate to continue processing.

**Osteochondral Tissue Processing**

Tissue processing is performed in an ISO class 5 room (Fig 4) located within the tissue bank by a member of the staff as soon as the team arrives in the facility. Processing is performed in a sterile room with negative pressure, organized using 3 tables. On the first table, 2 sterile flasks are prepared for before and after lavage (Fig 5A). All surgical instruments are positioned on the second table, such as clamps, scalpels, sterile drapes, syringes, oscillatory saws, batteries, and a lathe (Fig 5B). Finally, the third table is prepared with the sealer, scale, culture medium, and packages (Fig 5C).

The next step consists of cleaning plus removal of muscle and bone tissue not necessary for the transplant procedure and visual evaluation, with exclusion in the case of any articular cartilage injury. The first step of processing begins with the opening of 2 of the 3 sterile packages containing the tissue on the first table (Fig 6A). The physician responsible for processing catches the inner package, which is the most sterile, with a surgical clamp. The package is opened in a sterile (pre-lavage) flask. In this step, samples of the solution in which the tissue was immersed since harvesting are collected for microbiological analysis (fungi and anaerobic and aerobic bacteria) in culture flasks.
On the second table, tissue is fixed in a conventional lathe. Skeletonization begins with the removal of all remaining muscular and tendinous insertions (Fig 6 B and C), using scalpels and mechanical saws, leaving the proximal third of the humerus with only cartilage and bone (Fig 6D). During this step, it is important to make a few pauses to irrigation of the tissue with the pre-lavage solution to minimize damage to the humeral cartilage due to the heat caused by the mechanical saw. At the end of this step, a tissue fragment is collected for histopathologic evaluation (Fig 6E).

In the sequence, the tissue returns to the first table for continuous lavage with 0.9% saline solution in a second (post-lavage) flask. Three samples of this solution are collected for microbiological analysis (fungi and anaerobic and aerobic bacteria) in culture flasks (Fig 7A). Then, the tissue is dried with sterile compresses and transported to the third table, on which osteochondral tissue is measured with a graduated scale (Fig 7B). Tissue weighing is performed on a digital scale. After measurements, osteochondral tissue is stored in a sterile plastic package (internal package) containing the preservation medium, composed of Iscove’s cell culture medium without serum (Thermo Fisher Scientific, Waltham, MA) supplemented with 10% human albumin and vancomycin, 100 μg/mL, to reduce the risk of chondrocyte death (Fig 7C). Double and triple sterile package sealing is then performed. Double package sealing, in this step, is not easy because of the tissue size and owing to the preservation medium, which sometimes leaks, making adequate sealing more difficult.

Processed tissue is stored in the “quarantine refrigerator” until the results of all the microbiological and histopathologic tests are known (Fig 8). In the case of positive culture findings, the tissue is discarded. If findings are negative, tissue is ready for transplant and the patient’s surgery can be scheduled. All data are

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Fig 6. Tissue processing step-by-step: part 1. (A) Processing begins with the opening of 2 of the 3 sterile packages containing the tissue. (B, C) The tissue is fixed in a conventional lathe; then, skeletonization begins with removal of all remaining muscular and tendinous insertions. (D) The proximal third of the humerus is left with only cartilage and bone. (E) A tissue fragment is collected for histopathologic evaluation.
recorded in the corpse donor files and in the host patient files. Table 3 presents pearls and pitfalls regarding humeral head graft harvesting and processing.

### Osteochondral Tissue Transplantation Planning

Host osteochondral lesions are diagnosed by standard radiographs of the shoulder and computed tomography (CT). The goal of CT is to measure the size of the humeral head cartilage defect, besides identifying the absence of a posterior glenoid border fracture or bone avulsion of the infraspinatus or supraspinatus tendon. Axial CT images are obtained immediately below the coracoid process. A circle is positioned over the humeral head; a line is then drawn from the lesser tuberosity to the posterior margin of the cartilage adjacent to the infraspinatus insertion, and a second line is drawn tangent to the defect region toward the anterior line. The angle between these lines is denominated the defect angle (Fig 9). On the basis of the defect size, the size of the humeral head allograft can be determined.

On the surgery date, osteochondral allograft is transported in a cooled container at 4°C and removed from the package only at the moment of transplant (Fig 10A). At the time of surgery, an osteotomy is performed in the anatomic humeral neck of the graft for isolation of the fresh humeral head osteochondral allograft (Fig 10B), which is adapted for transplantation and filling of the cartilage defect, restoring the spherical humeral head anatomy (Fig 10C).

### Discussion

Owing to poorer long-term results of arthroplasty in young patients, alternative techniques that can be applied to patients younger than 50 years who present with major humeral head chondral lesions have been studied to restore the articular surface anatomy in a biological way using restorative techniques such as the fresh osteochondral allograft transplantation. Osteochondral allografts are similar to autografts and present the advantages of a shorter surgical time, lower harvest-associated morbidity, and the possibility of treating lesions larger than 2 cm.
The harvesting procedure requires a corpse donor and fitting of the articular geometry of the graft to the patient.\(^{10}\)

Osteochondral allografts can be fresh, when stored at 4°C, or frozen, when stored at −80°C. Frozen grafts at −80°C lead to a considerable reduction of the host immune response while preserving the biomechanical properties, although chondrocyte viability significantly decreases over time.\(^{11}\) Fresh osteochondral allografts refer to tissue harvested 24 hours after donor death and stored, almost aseptically, in a refrigerator at 4°C, until microbiological tests are performed to allow the transplant. This type of graft presents, as its main advantage, the fact that it contains hyaline cartilage with subchondral bone support, as well as viable chondrocytes at higher numbers.\(^{12-14}\) However, fresh osteochondral allograft viability decreases over time\(^{14,15}\) and with the medium used for storage.\(^{11}\)

Preservation of human osteochondral allografts has previously been studied for the treatment of knee lesions.\(^{16,17}\) Regarding the shoulder, few studies have evaluated the use of osteochondral allografts for treating humeral head articular cartilage lesions.\(^7\) The few existing reports have mainly described the use of frozen allografts,\(^7,18,19\) whereas studies involving the use of fresh allografts are scarce.\(^{20,21}\) Those studies, however, although rare, have presented promising results regarding the use of this type of graft, showing good functional results, pain improvement, and no complications. When chondrocytes remain viable during storage, they maintain matrix integrity and, so, the graft properties.\(^8\) Besides, long-term allograft transplant survival depends on graft chondrocyte viability, on matrix maintenance, and on the graft incorporation to host bone.\(^8,22-24\) Table 4 presents the advantages, disadvantages, and risks of the described technique. On the basis of this report, as described in this protocol, after adequate harvesting, transport, and storage, fresh humeral head osteochondral allograft is an adequate option for the treatment of patients with massive proximal humeral chondral lesions.

**Acknowledgment**

The authors thank “Ministério da Saúde” for the support.
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