



Configuration and Management of a Femoral Heads Bone Bank in a Specialised Tertiary Orthopaedic Hospital in Bucharest

IOAN CRISTIAN STOICA^{1,2}, ANA-MARIA MUNTEANU^{1*}, ALEXANDRU LUCHIAN¹,
CONSTANTIN NICOLAE¹, STEFAN MOGOS^{1,2}

¹Foisor Orthopedics Hospital Bucharest, 35-37 Ferdinand I Blvd, 021382, Bucharest, Romania

²Carol Davila University of Medicine and Pharmacy, 37 Dionisie Lupu Str., 020021, Bucharest, Romania

Abstract. *The purpose of the current paper is to describe the functioning protocol of a femoral heads bone bank in a specialised tertiary orthopaedic hospital in Bucharest and the results of its activity between January 2011 and December 2016. Since the initiation of the femoral head bone bank in 2011, we selected and tested 761 donors of femoral heads. Out of them, we implanted 435 grafts to a total of 242 recipient patients. We performed a thorough donor screening process, which resulted in a significant proportion of femoral head allografts discarded, mainly due to a positive hepatitis B or/and C viruses test or a positive result of the bacterial culture from the bone graft (in 3% of the grafts); the offending micro-organism was a Methicillin-Sensible Staphylococcus spp. Our bone bank may serve as a framework for developing similar structures by other hospitals in our country or elsewhere.*

Keywords: *allogenic bone graft, bone bank, femoral head*

1. Introduction

Reconstruction of bone defects is possible by using whether autologous or allogenic bone graft. Although autologous bone graft may be considered superior due to its concomitant osteoinductive and osteoconductive properties, its reduced availability and associated donor site morbidity may limit its use [1, 2, 3]. Allogenic bone grafts may be available in larger quantities due to bone banks. However, this type of graft has only osteoconductive properties, being thus only a frame for the newly formed bone.

Bone grafts are necessary for reconstructing significant bone defects that may result from trauma, extensive bone tumour resection or after bone infection [3, 4]; in spinal fusion procedures [5], in revision total joint arthroplasty [6] or revision anterior cruciate ligament reconstruction [7].

An allogenic bone graft can be obtained from banks that store tissues resulted from deceased patients [8, 9] or banks that store femoral heads from selected live patients who underwent a hip arthroplasty procedure. Besides the reduction in financial costs, these local bone banks offer the advantage of easy access to the graft, an issue of the highest importance especially for secondary and tertiary orthopaedic centres with numerous procedures for which bone graft material is mandatory.

Bones are made up of cells embedded in a mineralized organic matrix. The matrix consists of 30% organic components and 70% inorganic components. The organic components are represented mainly by type I collagen, while the inorganic components consist primarily of hydroxyapatite and other salts of phosphate and calcium. The major inorganic component is hydroxyapatite ($\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$). Additionally to the calcium and phosphate salts, minerals as sodium, potassium, magnesium and carbonate are also found.

The purpose of the current paper is to describe the functioning protocol of a femoral heads bone bank in a specialised tertiary orthopaedic hospital in Bucharest, organised under the national and European transplant regulations, and the results of its activity between January 2011 and December 2016, as an experience that may serve as a framework for developing similar structures by other hospitals.

*email: ammunteanu@gmail.com



2. Materials and methods

2.1. Bone bank protocol

The bone bank of the Foisor Orthopaedic Hospital Bucharest, functioning since 1 January 2011, was the first bone bank in Romania approved to harvest, process, store and release for implantation of the femoral heads obtained from patients who underwent total hip arthroplasty procedures in the same hospital. The bank recycles the femoral heads which otherwise should have been destroyed and discarded as biologic waste. The stored femoral heads are used only for the hospital's patients; the bank does not export bone grafts to other medical institutions (hospital bank). This protocol includes a detailed description of the bank's organisation, donor selection and screening, technical resources, preparation and storage, graft allocation.

2.2. Ethics

According to the Romanian law, since 2006 the removal of the femoral head from a living donor, having a therapeutic goal, may and can be done without the approval of a Donation Commission. However, it has to respect the main ethical principles: the risk for the donor's health should be evaluated and minimised to as low as possible; the donor has to give his informed consent for donation, which must remain anonymous and confidential.

2.3. Staff

The employees of the hospital represent the only staff involved in the activity of the bone bank. There is no extra person employed explicitly for working in the bank. The full responsibilities of each staff member are mentioned in the job description. A medical doctor (anesthesiologist) is the head of the bank, responsible for the organisation and proper functioning of the unit. One of the orthopaedic surgeons is responsible for quality management - he ensures that the femoral heads available for transplantation respect the donation, harvesting, screening, storage and allocation standards. The coordinating nurse of the operating theatre and a technical surgical nurse are responsible for the implementation and integration of the bone bank protocol in the operating theatre. All teams of surgeons, containing a senior surgeon, are capable and allowed to harvest femoral heads. The surveillance of postoperative evolution and future adverse effects or complications of the grafted patients is the responsibility of other surgeons.

2.4. Specific protocols and documentation

For the proper functioning of the bone bank, working protocols of every step of activity have been established. Accurate and complete documentation of their implementation is necessary, which includes:

2.4.1. Methods of identification of the donor

2.4.2. Exclusion criteria of the donors:

- a. History of hepatitis B, hepatitis C, HIV or syphilis
- b. History of malignancy
- c. History of neurological degenerative diseases
- d. History of treatment with Human Growth Hormone
- e. History of cornea or dura mater transplantation
- f. Elevated acute inflammatory tests
- g. Elevated liver enzymes
- h. Diagnosis of hip arthritis or systemic infection
- i. Autoimmune diseases



2.4.3. Methods of screening the donors

- a. Questionnaire for evaluating the epidemiological risk of the donor
- b. Clinical exam, imagistic exam, standard biologic work-up for clearing acute disease or exacerbation of a chronic pathology
- c. Informed consent form for donation, signed by the donor before surgery
- d. Serological and bacteriological screening tests performed from the blood and bone graft sample at the time of the surgical procedure:
 - Immunology tests – HBsAg, anti-HBs, anti-HBc, anti-HCV
 - Virology tests – anti-HIV₁, anti-HIV₂, HTLV (Human T-lymphotropic virus), cytomegalovirus (CMV) test
 - Microbiology tests - VDRL, TPHA (blood) and bacterial culture from the bone graft / soft tissue sample
 - Viral NAT tests – PCR HBV, PCR HCV, PCR HIV
 - Blood type/Rh

2.4.4. The unique registration code of the graft

A single code is allocated to every harvested femoral head. This code will never change during the life of the graft, as it is its primary form of identifying and tracing

2.4.5. Graft transplantation form

shows grafts traceability (who was the donor and the receiver)

2.4.6. Graft quality form

Assesses that the screening of the patient and the harvesting, processing and storage conditions were respected.

2.4.7. Graft destruction form

It is necessary for the grafts of donors not cleared by the laboratory screening or grafts damaged due to accidental improper storage conditions

2.4.8. Adverse reactions form (observed postoperatively)

The anesthesiologist and the surgeon responsible for the management of the patient will identify donors inclusion and exclusion criteria. The final decision belongs to the orthopaedic surgeon who takes into consideration the clinical and the imagistic examination, the history and the epidemiological risk profile of the patient resulted from the "Questionnaire."

2.5. Security quarantination and validation

After completion of documentation, if abnormalities were not detected, the graft is cleared as suitable for transplantation. Each code of graft is added to a security tag. The graft changes its location, from the "expecting in quarantine" deep freezer to a second deep freezer containing only "validated" grafts suitable for transplantation.

All unsuitable grafts are destroyed. Serological screening for infectious diseases is not repeated six months after surgery as, according to the European Union Regulation Commission 86/2006, this is not mandatory if a disinfection method is used. We use thermic disinfection at 80° C for 90 minutes.

2.6. Technical resources

The availability of adequate equipment is a necessary condition for the preservation of the biological and mechanical properties of the grafts.



2.6.1. Air quality

From the beginning of the process, the air quality during harvesting and processing the graft is a critical factor that may influence the risk of contamination.

The operating rooms of our hospital are equipped with vertical laminar flow filtered by 13 H HEPA filters, that deliver Grade A purity of air, as defined in the European Guide to Good Manufacturing Practice, volume 4-Annex two and Commission Directive 2003/94/EC. We monitor the air quality by performing serial particle counts, every six months or sooner if necessary (unexpected rise in room positive pressure) and microbial colony counts every month.

Graft harvesting takes place in the operating room, being a normal process during a hip arthroplasty procedure. The primary processing area is a sterile surgical instrument table placed inside the operating room under the laminar flow central area.

In this area, in sterile conditions, one of the surgeons and one nurse of the surgical team performs the lavage of the removed femoral head with 250 ml of saline. A sample consisting of a small piece of bone, insertion of the *ligamentum teres* and synovial tissue is harvested for microbiology testing. The size (diameter) of the femoral head is measured, followed by the abrasion of the articular cartilage. The graft is further placed into a sterile, unbreakable, double-walled, watertight box (type TELOS®), locked in the operating room. The sterile locked box is transported to the disinfection area of the bone bank room, where the graft undergoes a process of thermal disinfection, using a specific device, The Lobator Marburg device.

2.6.2. Thermal disinfection

A Lobator Marburg device is used for the thermal disinfection of the femoral heads. It exposes the grafts to a temperature of 80°C (measured in the centre of bone heads with a max of 56 mm diameter) for 90 min. The femoral head is placed into the disinfection container without fluid since the formation of ice crystals later on, in the deep-freezer, would destroy the bone structure.

The automatic disinfection process comprises three phases: the heat-up phase, the steady-state temperature phase and the cool-down phase. The electronic control system guarantees a temperature of 82.5°C within the centre of the femoral head for 15 minutes. If the disinfection process has run through undisturbed, the annotation "Process Completed" appears at the end of the protocol. A disturbance or an interruption of the process is documented as "Process Aborted". The defrost program takes 8 minutes and can be repeated several times.

No quarantine storage and no second testing of the donor are necessary when using this device after having screened the donors by NAT -tests for HIV, HBV, and HCV (10).

2.6.3. Storage in a low-temperature freezer

After a 120 minutes cooling period, the box is tagged with its unique registration code and is stored in the first low-temperature freezer (-80°C), where it remains quarantined until the confirmation of the laboratory screening results of the donor (at least 11 days).

After completing the donor file with all the necessary documents that clear the bone graft, it is tagged with an additional quality tag and transferred to the second low-temperature freezer (-80°C), containing only validated safe grafts. The most extended period of storage was two years.

The bone bank is represented by a 30 sqm room inside the operating theatre, where temperature (19-21° C) and humidity values (35-45%) are kept constant. The room has a fire alarm, a secured and limited access system, a PC integrated into the hospital system network, where data of the bone bank are managed with specific software that also controls data access.

The file of the femoral head and the medical records of both patients (donor and receiver) are compulsorily being stored for 30 years after transplantation. The detection and registration of postoperative complications attributable to the graft are the jobs of a different delegated surgeon of the team.



2.7. Allocation

When a surgeon decides to use an allograft during a surgical procedure, the box containing the femoral head is removed from the second freezer, three hours before surgery and thawed at room temperature inside the storage room. The complete documentation is re-checked, and the graft is transported to the operating room when needed by the surgeon.

3. Results and discussions

Since the initiation of the femoral head bone bank in 2011, we selected and tested 761 donors of femoral heads. Out of them, we implanted 435 grafts to a total of 242 recipient patients.

The principal diagnosis in the recipient patients who needed the bone grafts was: difficult primary hip arthroplasty or revision total hip arthroplasty, spinal fusion procedures, tumoral pathology or for managing complications of fractures. There were no septic complications imputable to the bone grafts. There were no severe adverse reactions related to graft transplantation.

Because of the thorough donor selection process, a significant proportion (up to 40%) of femoral head allografts were discarded, mainly (90-95%) because of hepatitis B or/and C viruses positive tests. The increased prevalence of viral hepatitis in this asymptomatic patient population (with normal hepatic enzymes and no history of jaundice), could have been a consequence of the poor socio-economic and medical conditions in our country, during the former political regime, decades ago when VHB was "endemic".

Every year 3 to 4% of the grafts were discarded because of a positive result of the bacterial bone culture. The offending micro-organism was a Methicillin-Sensible *Staphylococcus* spp. As no infection was detected in patients, neither in donors after hip replacement nor in recipients, we concluded it was a process of external contamination during the processing phase.

Bone allograft transplantation is increasingly used in orthopaedic procedures since its introduction in 1981, due to the growing need for bone grafts [11]. Significant improvements concerning documentation, donor selection, processing, storage and allocation have taken place during the last years, since the implementation in the national legislation of the European Community Standards, beginning with 24/2004/EC, mandatory for the proper functioning of an orthopaedic bone bank.

The main concern regarding allograft bone banks is the possible transmission of infectious diseases [12, 13, 14, 15, 16]. Since perfect sterilisation might not be possible, grafts from donors presenting with viral burden should be avoided (discarded).

The Lobator Marburg device, consisting of an electronic heating unit and the sterile disinfection set box, validated by the German Federal Institute for Drugs and Medical Devices, is used since 1993, for the thermal disinfection of the femoral heads [17]. This compact system has been demonstrated to inactivate HIV 1, HIV 2, HTLV, CMV, Hepatitis B and C as well as *Treponema Pallidum* and vegetative bacteria, increasing the safety of the allogenic bone graft while maintaining its biomechanical and biological valences (18, 19, 20).

Concerning the exogenic bacterial contamination of the graft during its harvesting and processing, finding the best method to manipulate the graft and to disinfect it will lower the percentage of discarded grafts. Quality of air seems to be necessary, but some studies find it less critical than considered before [21].

The use of the thermal method of sterilisation completing the screening of the donor's serology by NAT testing renders repeating the testing after six months from surgery not necessary; however, it did not lower the costs of grafts quarantine.

Many hospitals in many countries, regardless of their GDP, have opened such Hospital Banks and are still looking for ways to improve their performance. Besides bone banks in Germany, [17-19] we found banks protocols described in several European countries: Netherlands [22], England [23], Croatia [24], France [21], Spain [25], Portugal [26] as well as in Marocco [27], Canada [28], USA [29], Argentina [30], Chile [31], Australia [32, 33], India [34], Hong Kong [35].



Our bank performs in the medium range compared to banks in other countries, with a very high discarding rate of 30-40% due to the presence of viral hepatitis B and C, but only 3% exogenous Staphylococcal contamination, that could have been avoided. Other banks reporting comparable figures were in Ireland [23] in 2015, Portugal [26] in 2000 and Argentina [30] in 2015.

The price of an allograft femoral head varies from 610 £ in a Swedish bank in 2014 to 1367 Euro in England in the same year. The prices in the USA have the same trend [29]. Compared with the use of commercially available processed allografts, these hospital banks offer an important saving of Euro/year [39]. In Germany, in 2013, the expenses for one thermal disinfected femoral head was 274 Euro vs 535 Euro in a tissue service [36, 37]. The cost of our bank graft was 950-1100 Euro, leaving space to methodology amelioration.

Finding new techniques of viral screening, with higher sensitivity and specificity, as well as finding the most efficient disinfection method, that will not damage the mechanic properties of the bone and its immunogenicity [38] will hopefully solve the problems of allograft banking.

4. Conclusions

Medical and economic aspects should be considered for this non-sophisticated design and management of an orthopaedic bone bank of femoral heads in a specialised tertiary orthopaedic hospital in Bucharest. It may serve as a framework for developing similar structures by other hospitals in our country or elsewhere.

References

1. SUMMERS BN, EISENSTEIN SM. Donor site pain from the ilium. A complication of lumbar spine fusion. *J Bone Joint Surg Br.*, **71**, 1989, p. 677
2. SUDA AJ, SCHAMBERGER CT, VIERGUTZ T. Donor site complications following anterior iliac crest bone graft for treatment of distal radius fractures. *Arch Orthop Trauma Surg.* **139**, 2019, p 423
3. MANKIN HJ, GEBHARDT MC, JENNINGS LC, SPRINGFIELD DS, TOMFORD WW. Long-term results of allograft replacement in the management of bone tumours. *Clin Orthop Relat Res.*, **324**, 1996 p 86
4. LOCKER PH, ARTHUR J, EDMISTON T, PURI R, LEVINE BR. Management of Bone Defects in Orthopedic Trauma. *Bull Hosp Jt Dis.*, **76**, 2018, p 278
5. RAIZMAN NM, O'BRIEN JR, POEHLING-MONAGHAN KL, YU WD. Pseudarthrosis of the spine. *J Am Acad Orthop Surg.*, **17**, 2009, p 494
6. LEI PF, HU RY, HU YH. Bone Defects in Revision Total Knee Arthroplasty and Management. *Orthop Surg.*, **11**, 2019, p 15
7. DIERMEIER T, HERBST E, BRAUN S, et al-Outcomes after bone grafting in patients with and without ACL revision surgery: a retrospective study. *BMC Musculoskelet Disord.*, **19**, 2018, p 246
8. VEEN MR, RIETVELD DC, BLOEM RM. The use of allogeneic bone and tendon tissue from a central bone bank. *Ned Tijdschr Geneesk.*, **135**, 1991, p 2028
9. SHIBUYA N, JUPITER DC. Bone graft substitute: allograft and xenograft. *Clin Podiatr Med Surg.*, **32**, 2015, p 21
10. PRUSS A, SEIBOLD M, BENEDIX F, FROMMELT L, VON GARREL T, GÜRTLER L, DÖRFFEL Y, PAULI G, GÖBEL UB. Validation of the Marburg bone bank system for thermosinfection of allogeneic femoral head transplants using selected bacteria, fungi and spores. *Biologicals*, **31**, 2003, p 287, *Injury.*, **48**, 2017, p 1283
11. VON GARREL T, KNAEPLER H, GÜRTLER L. Inactivation of HIV-1 in human femur heads using a heat disinfection system. *Unfallchirurg.*, **100**, 1997, p 375
12. HOFMANN C, VON GARREL T, GOTZEN L. Bone bank management using a thermal disinfection system. A critical analysis. *Unfallchirurg.*, **99**, 1996, p 498



- 13.KNAEPLER H, VON GARREL T, SEIPP HM, ASCHERL R. Experimental studies of thermal disinfection and sterilisation of allogeneic bone transplants and their effects on biological viability. *Unfallchirurg.*, **95**, 1992, p 477
- 14.FÖLSCH C, MITTELMEIER W, BILDERBEEK U. Effect of Storage Temperature on Allograft Bone. *Transfus Med Hemother.*, **39**, 2011, p 36
- 15.PRUSS A, CASPARI, G, KRÜGER D. Nucleic Acid Amplification Tests for HIV, HBV, and HCV in Tissue Donors: Useful or Dispensable? *Med Hemother*, **35**, 2008, p 421
- 16.NIKOLAOU VS, GIANNOUDIS PV. History of osteochondral allograft transplantation.
- 17.ZWITSER EW, JIYA TU, GEORGE LICHER H, VAN ROYEN BJ. Design and management of an orthopaedic bone bank in The Netherlands. *Cell Tissue Bank.*, **13**, 2012, p 63
- 18.JAMES LA, IBRAHIM T, ESLER CN. Microbiological culture results for the femoral head. Are they important to the donor? *J Bone Joint Surg Br.*, **86**, 2004, p 797
- 19.ZAMBORSKY R, SVEC A, BOHAC M, KILIAN M, KOKAVEC M. Infection in Bone Allograft Transplants. *Exp Clin Transplant.*, **14**, 2016, p 484
- 20.CRNOGACA K, BICANIC G, DELIMAR D. Antibiotics in frozen bone grafts can cause allergic reactions in recipient patients. *Med Hypotheses.*, **84**, 2015, p 107
- 21.BUSIC M. New Croatian legislation on tissue banking, *Acta Med Croatica.*, **61**, 2007, p 445
- 22.WARNOCK JM, ROWAN CH, DAVIDSON H, MILLAR C, MCALINDEN MG. Improving efficiency of a regional stand alone bone bank, *Cell Tissue Bank.*, **17**, 2016, p 85
- 23.LOUART B, CHARLES C, NGUYEN T-L, BUILLES N, ROGER C, LEFRANT J-Y. Microbial contamination and tissue procurement location: a conventional operating room is not mandatory. An observational study. *PLoS One.*, **8**, 2019, p 14
- 24.MIRABET V, ÁLVAREZ M, LUIS-HIDALGO M, GALAN J, PUIG N, LARREA L, ARBONA C. Detection of hepatitis B virus in bone allografts from donors with occult hepatitis B infection. *Cell Tissue Bank.*, **18**, 2017, p 335
- 25.JUDAS F, TEIXEIRA L, PROENCA A. Coimbra University Hospitals bone and tissue bank twenty-two years of experience, *Transplant Proc.*, **37**, 2005, p 2799
- 26.CHAHBOUNI M, RAMI A, MORHIT ME, KHARMAZ M, BERRADA MS, YAACOUBI ME. Creation of the bone bank of the Rabat and Casablanca region in Morocco, *Pan African Medical Journal*, **29**, 2018, p 210
- 27.LA PRAIRIE AJ, GROSS M. A simplified protocol for banking bone from surgical donors requiring a 90-day quarantine and an HIV-1 antibody test. *Can J Surg*, **34**, 1991, p 41
- 28.BROWN DA, MALLORY GW, HIGGINS DM, ABDULAZIZ M, HUDDLESTON PM, NASSR A, FOGELSON JL, CLARKE MJ. A cost-effective method for femoral head allograft procurement for spinal arthrodesis: an alternative to commercially available allografts. *Spine (Phila Pa 1976).*, **39**, 2014, p 902.
- 29.HOVANYECZ P, LORENTI A, LUCERO JM, GORLA A, CASTIGLIONI AE. Living donor bone banking: processing and discarding--from procurement to therapeutic use. *Cell Tissue Bank.*, **16**, 2015, p 593-603.
- 30.CALVO R, FIGUEROA D, DIAZ-LEDEZMA C, VAISMAN A, FIGUEROA F. Bone allografts and the functions of bone banks. *Revista Medica de Chile.*, **139**, 2011, p 660
- 31.SOMMERVILLE SM. Contamination of banked femoral head allograft: incidence, bacteriology and donor follow up. *Aust N Z J Surg.*, **70**, 2000, p 480
- 32.CAMPBELL DG, OAKESHOTT RD. Bone allograft banking in South Australia, *ANZ J Surg*, **65**, 1995, p 865
- 33.LAKHWANI OP, JINDAL M, KAUR O, CHANDOKA RK, KAPOOR SK. Effect of bone bank processing on bone mineral density, histomorphometry and biomechanical strength of retrieved femoral head. *Indian J Med Res*, **146**, 2017, p 45
- 34.LEUNG HB, FOK MW, CHOW LC, YEN CH. Cost comparison of femoral head banking versus bone substitutes. *J Orthop Surg (Hong Kong).*, **18**, 2010, p 50



35.KAINER MA, LINDEN JV, WHALEY DN, HOLMES HT, JARVIS WR, JERNIGAN DB, ARCHIBALD LK. Clostridium infections associated with musculoskeletal-tissue allografts. *N Engl J Med.*, 350, 2004, p 2564

36.BENNINGER E, ZINGG PO, KAMATH AF, DORA C. Cost analysis of fresh-frozen femoral head allografts: is it worthwhile to run a bone bank? *Bone Joint J.*, **96**, 2014 Oct, p 1307

37.JUNG S, KAPPE T, BIEGER R, REICHEL H. Cost-effectiveness of a local bone bank based on thermoinfection according to §20 band c AMG and alternatives. *Z Orthop Unfall.*, **151**, 2013, p 291

Manuscript received: 16.02.2020