

Bone and Tissue Allograft Use by Orthopaedic Surgeons

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Abstract: The purpose of our study was to determine the involvement of orthopaedic surgeons in the process of acquiring allografts they transplant. A questionnaire regarding allograft acquisition and use was directed to 340 hospitals. In approximately 85% of the institutions, nonorthopaedic personnel selected and acquired the allografts. In most, those responsible for providing surgeons with allografts had little or no knowledge of the practices of tissue banking and allograft transplantation biology. In about 15% of the hospitals, the surgeon was involved in the selection of the source of allografts. It is imperative that orthopaedic surgeons who transplant bone and tissue allografts become actively involved in determining the source and processing of tissue transplants they place in their patients. **Key words:** bone, tissue, allograft, bank, orthopaedic surgeons.

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Over the past decade more than 5 million bone tissue allografts have been transplanted in the United States, including approximately 875,000 in 2001 alone [1,2]. These transplants have gained importance as reliable adjuncts in joint arthroplasties and spinal surgery, as well as in pediatric, general orthopaedics, and sports medicine [3–11]. Massive allografts have also been used for several decades to replace bone and joints lost because of metallic implants and the excision of bone tumors [12–14].

Tissue banks use a variety of techniques in bone allograft excision and preparation. Donors normally undergo screening histories (from next of kin or medical records, for instance) and physicals, with the addition of screening laboratory tests for transmissible diseases. For the bone and tissue procurement, tissue banks follow directives that can vary from institution to institution. On one end of the spectrum lies aseptic excision and processing of bone in an operating room environment. On the other end lies the excision of bone, without aseptic precautions, in the morgue or a funeral home with reliance on secondary sterilization [15,16]. The aseptic technique of bone and tissue procurement involves removing the allograft tissue in a sterile operating room environment after the donor has been washed in a separate preparation room. This is usually performed as soon as possible after death of the donor, with general limits of 24 hours if the body has been refrigerated or 12 hours if it has not been refrigerated. In some cases the procurement would be performed immediately after the harvesting of visceral organs such as the heart, liver, or kidneys. The donor's body is prepared and draped

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in a similar fashion to that used during surgery. Cultures are obtained at least once on the tissues harvested. Various solutions, such as antibiotics, surfactants, and alcohols, may be used to prepare the allograft tissue.

The method of secondary sterilization, also known as terminal sterilization, is used in the cases in which the allografts are not obtained in an aseptic technique [16]. With the increased risk of disease transmission, gamma irradiation or ethylene oxide are used secondarily sterilize the allografts. This, however, can present the problem of alterations in the biomechanical properties of the grafts. Also, the methods of allograft preparation have a direct bearing on the biologic properties of the graft, the potential for disease transmission or postoperative infection, and the assurance that can be given to patients. Graft preparation is also of utmost importance in producing an integration of the bone graft into the host bone, conferring success to the implantation [15,17].

Bone and tissue allografting can offer the advantage of allowing the surgeon to place a graft of the same anatomic location, and thus with very similar mechanical and osteoconductive properties, as the recipient site. In addition, bone allografting offers the advantages of osteoinduction through osteoinductive factors that are still present in the graft. Regarding immunogenicity, bone and tissue allograft tissues can elicit immune responses in the hosts. This is normally mediated via class I and II major histocompatibility complex (MHC) antigens. However, because cell death occurs with tissue processing, whether this is performed after aseptic procurement or during terminal sterilization, the magnitude of a possible immune reaction is considerably diminished [18].

Although bone and tissue allografts are now transplanted by large numbers of orthopaedic surgeons, many of the surgeons appear to be unfamiliar with their preparation and processing, as well as their use as safe and effective implants. To determine whether or not such is the case this study was undertaken. The objective of this study was to ascertain the degree of familiarity orthopaedic surgeons have with techniques of bone banking and their involvement in the selection and procurement of allografts within their hospital environment.

Materials and Methods

The study was performed at 340 hospitals from different regions in the United States. These hospitals comprise a single for-profit group of hospitals.

Table 1. Type and Use of Allografts

Type of Allograft	Average Percentage Used by Surgeons
Crushed or morselized bone	73.7
Cortical bone plates	13.2
Iliac crest wedges	47.4
Ilium strips	15.8
Femur heads or condyles	44.7
Proximal femurs	21.1
Osteoarticular allografts	5.3
Bone-patellar tendon-bone	28.9
Achilles tendon	15.8
Ribs	21.1
Mandibles	7.9
Dura mater	21.1
Others	52.6

Orthopaedic surgeon familiarity with bone banking techniques as well as specific questions about tissue and bone allografts was assessed with a questionnaire sent to these hospitals (Appendix A).

The questionnaire focused on allograft acquisition details and implantation of bone or tissue allografts by surgeons in hospitals, the type and number of transplantations performed and the methods of graft preservation. It also inquired on the degree of the surgeon's involvement in the selection of the graft and the knowledge level of the individual who requested the graft if this was not the surgeon. The tissue banks used for obtaining grafts were also assessed.

The questionnaires were directed to the operating room supervisors for completion with a request to obtain necessary information from the surgeon. As the questionnaires were returned, data were included into a database for adequate analysis. A total number of 236 institutions provided responses, for a response rate of 69.4%. All responding institutions were included in the final analyses.

Results

Of the 236 responding institutions, 168 hospitals transplanted bone or tissue allografts while 68 did not. The total number of 15,308 allografts was transplanted during a 12-month period in all institutions included in the survey. The type and usage of allografts is depicted in Table 1. The actual estimated cost of the implanted allografts in all hospitals exceeded \$8,260,000.

The most frequently used allografts were those sterilized by irradiation, followed by aseptically procured and processed allografts. Ethylene oxide ster-

ilized allografts were third on the list. Sixty-five percent of operating rooms at the institutions surveyed had on file a statement from the tissue banks from which the allografts had been obtained listing all tests and screening procedures performed on the donors of allografts. Thirty-five percent of operating rooms did not have this information on file.

The subspecialty to request the largest number of bone allografts was orthopaedic surgery followed by neurosurgery and oral and maxillofacial surgery. With respect to the familiarity with tissue banking of physicians requesting the allografts, 65% did not know which tissue banks these were obtained from or how the allograft was processed. In about 85% of the institutions, the tissue transplants were obtained by nonorthopaedic personnel. In the majority, the individual responsible for providing surgeons with allografts had little or no knowledge of the practices of the tissue banks from which the grafts were obtained. The tissue banks were selected, in order of importance, for allograft availability, delivery, cost, and, finally, for method of excision and allograft preparation.

The surgeon was involved in the selection of the source of the allograft in about 15% of the hospitals. Also, 34% of the surgeons were unaware of the processing methods of the allografts they were transplanting. Most surgeons did not know the allografts they used were secondarily sterilized.

Discussion

The number of revision knee and hip arthroplasties has increased steadily in the past decade. More than 10% of the total hip arthroplasties performed in the United States are of the revision type. The use of allograft bone for reconstructing deficient bone has increased at similar rates [19,20]. Allografting of the spine likewise increased dramatically [21]. Our study revealed that in a 1-year period, more than 15,000 allografts were transplanted in 168 hospitals. Despite this increase, surgeons implanting allografts were not included in the purchase process of allograft tissue.

Most orthopaedic surgeons transplanting allografts were not involved in the selection process, and the personnel responsible for ordering did not know from which tissue banks the allografts were obtained or how they were processed. This occurred despite recommendations by American Association of Orthopaedic Surgeons and various authors that they be familiar with the tissue bank used and the allograft tissue practices [9,13,14,22,23]. Fortunately, most tissue banks in the United States are

accredited by the American Association of Tissue Banks (AATB) or adhere to its standards. These include the acquisition of a history from next of kin, physical examination of the potential donor to rule out transmissible infections or evidence of high-risk behavior, and confirmation of negative laboratory results for antibodies against type 1 and type 2 human immunodeficiency virus (HIV), hepatitis B surface antigen (HBsAg), hepatitis C virus (HCV), human T-lymphotropic virus type I, and syphilis [24].

In donor selection, all tissue banks adhered to U.S. Food and Drug Administration (FDA) rules, but these rules do not include tissue processing, and requirements for donor testing are limited [25,26]. Moreover, even tissue practices vary amongst AATB-accredited tissue banks. Vangness et al. [27] surveyed 42 tissue banks that were either accredited or undergoing accreditation review by the AATB. The results showed different tissue procurement methods, sterilization and storage methods, and time elapsed between death and tissue harvesting in cadaveric donors, among other parameters, with nearly half of the tissue banks having the tissue processing performed exclusively by outside organizations.

Few orthopaedic surgeons (15%) participated directly in the allograft selection, according to the hospitals surveyed. The selection was performed mostly by nonorthopaedic personnel with little knowledge on the basic principles of bone banking. Influence of orthopaedic supply company representatives is also considerable as are promotional pamphlets, many of which are not based on published laboratory or clinical data.

Orthopaedic surgeons and personnel ordering bone allografts for surgical procedures should be aware of the differences in properties of various allograft preparations. According to the present study, the most frequently used methods of assuring graft sterility was irradiation. Irradiated allografts are used by many surgeons. This is mostly because of the belief that irradiation will prevent HIV transmission, thus making it worthwhile to trade safety for the loss of osteoinduction and alteration of biomechanical properties of the bone [28,29]. However, a study performed by Smith et al. [30] shows that, even at doses at which tissue quality begins to be compromised (1.5-2.5 Mrads), irradiation failed to be virucidal for HIV type 1.

Freeze-dried and frozen aseptically processed bone and tissue allografts have been reported in many circumstances to perform as well as fresh autografts [3,6,8]. With extensive processing, the

incorporation of avascular bone grafts into host bone may decline [15]. Frozen allografts were the most frequently used in the hospitals surveyed. However, freezing processes vary. Bone may be frozen rapidly to cryogenic temperatures and stored at below -120°C . It may be frozen to -70°C to -80°C , or it may be frozen in conventional -20°C freezers [8,17]. So-called cryopreservation, that is, control velocity cooling after exposure to cyroprotective agents, favors survival of cells, and has been used continuously only for preservation of osteochondral allografts [15,17]. The use of this technique for preservation of other tissues offers no advantage and probably increases immunogenicity of these grafts [31,32].

For the most part, allografts are frozen or freeze-dried not only to preserve them but also to reduce antigenicity and thus rejection by the host [18]. This is rarely mentioned in allograft promotions, or are individuals bringing allografts to the hospitals versed in bone transplantation biology. This clearly places the burden of informed selection of allografts in the hands of orthopaedic surgeons; however, our study showed that a significant percentage of orthopaedic surgeons are not involved in the selection process. For instance, many of the ordering employees surveyed were not aware that some of the allografts they transplanted were secondarily sterilized. Tissue harvesting can be performed either aseptically or in a nonsterile fashion. Secondary sterilization produces changes in the biologic and biomechanical properties of the graft. Mechanical properties of tissues may be adversely affected by irradiation [1,28,29]. Ethylene oxide may produce inflammation and impair healing, unless it or its by-products are removed from the graft [33]. The FDA has set acceptable limits for these [34].

The questionnaire used in this study had an acceptable response rate (69%). We believe that responses provided allowed for an adequate conclusion to be drawn from the study. The questionnaire was straightforward and did not raise any serious questions as to the nature of information sought. We recognize that this form of data collection may be subject to error. Nevertheless, it showed a trend of nonparticipation in the selection of transplanted material by orthopaedic surgeons.

Allografts represent the only transplanted material used in orthopaedic surgery selected by nonsurgeons. This common practice excludes orthopaedic surgeons from having direct bearing on the care provided to the patients. Because orthopaedic surgeons use bone banks on a regular basis, they should increase their knowledge of bone banking practices and should be informed on the quality

assurance of the allograft tissue that they implant in their patients. With the current emphasis on the hospital costs, it is also imperative that orthopaedic surgeons become actively involved in determining the source, selection process, and processing of tissue allografts and cost of the transplants they place into their patients. Ideally, orthopaedic surgeons should use bone and tissue allografts from tissue banks that meet or exceed AATB, FDA, and American Red Cross standards, do not have prolonged periods between donor death and tissue harvesting and processing, and adhere to the highest standards of aseptic technique when harvesting, processing, and storing allograft tissues with verifiable quality control checks during each of the stages of tissue banking.

Orthopaedic surgeons using allografts must be aware of the potential problems related to allograft tissue use. They can make an informed decision in this regard only if they are familiar with bone banking procedures.

Appendix A. Hospital Bone Banking Questionnaire

Name of Hospital _____

1. In the past 2 years, has your operating room obtained bone or tissue allografts?

Yes No

If the answer is no, please return the questionnaire. If yes, proceed to the next questions.

2. Types and number allografts transplanted in the past 12 months:

Yes	No	Type of Allograft Used	Approximate number
		Crushed, morselized, or ground bone	
		Bone plates	
		Iliac crest wedges	
		Bone plugs (Dowels)	
		Ilium strips	
		Femur heads or femoral condyles	
		Diaphyseal bone (bone shafts)	
		Proximal femurs	
		Osteoarticular allografts	
		Bone-patellar tendon-bone	
		Achilles tendon	
		Ribs	
		Mandibles	
		Dura mater	
		Others (please specify)	

3. Method of preservation of allografts (check each that apply):

Freeze-dried	<input type="checkbox"/>
Frozen	<input type="checkbox"/>
Cryopreserved	<input type="checkbox"/>
Fresh	<input type="checkbox"/>

4. Of the allografts used, check method of preparation:

Aseptic procurement and processing	<input type="checkbox"/>
Ethylene oxide sterilization	<input type="checkbox"/>
Irradiation	<input type="checkbox"/>

5. Does the operating room have on file a statement from the tissue banks from which the allografts have been obtained listing all tests and screening procedures performed on the donors of allografts?

Yes No

6. Specialties requesting bone and tissue allografts:

Orthopaedic surgery	
Neurological surgery	
Oral and maxillofacial surgery	
Plastic surgery	
General surgery	
Other	

7. Do the requesting surgeons specify from which tissue bank they wish to obtain the allografts?

Yes No Sometimes Never

8. Who makes the decision concerning the selection of a tissue bank to service your hospital?

Operating room supervisor	
Other operating room nurses	
Hospital administration	
Transplanting surgeons	
Other	

9. Basis on which is the selection of tissue banks made:

Method of excision and allograft preparation	
Cost	
Availability/delivery	

10. List the tissue banks from which your hospital has obtained allografts in the past 2 years:

_____	_____
_____	_____
_____	_____

11. When allografts are brought into the operating room, are the surgeons told the allografts have been processed in a particular manner?

Yes No

12. Has the supply of allografts on a "when needed" basis been satisfactory and adequate?

Yes No

13. Estimate of total cost of bone and tissue allografts used in your hospital on an annual basis:

14. Would you like for the (name of our hospital system) to produce a pamphlet dealing with the selection and acquisition of bone and tissue for clinical transplantation?

Yes No

15. Name and address of an individual to whom future communications regarding bone and tissue banking should be addressed:

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