Trends in Bone Graft Use in the United States

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Abstract

Bone graft and bone graft substitutes are used to provide structural support and enhance bone healing. Autogenous, allogeneic, and artificial bone grafts each have advantages and drawbacks. The development of allografts, synthetic bone grafts, and new operative techniques may have influenced the use of bone grafts in recent years. The goal of this study was to analyze the use of bone grafts and bone graft substitutes in the United States during a 16-year period. Using data from the National Hospital Discharge Survey, the authors analyzed the use of autogenous and artificial bone grafts in almost 2 million patients in the United States between 1992 and 2007 using International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) codes in 4 periods (1992-1995, 1996-1999, 2000-2003, and 2004-2007). Among an estimated almost 2 million bone graft procedures (83% autogenous, 17% artificial), the use of both types of grafts decreased. The main diagnoses for which bone grafts were used did not change; however, cervical spine diseases and lower-limb fractures decreased more remarkably. Although sex (52% male in the early 1990s to 47% in 2000-2003) and discharge status (more discharges to a short-term or long-term-care facility) significantly changed, age increased from 47 to 53 years and inpatient days decreased significantly from 6 to 5 days during the study period. The use of bone grafts and bone graft substitutes is decreasing in the United States, with a slight shift from autogenous to substitute grafts.
Bone grafts are used to facilitate the union of fractures, osteotomies, arthrodeses, and nonunions, particularly when there is a bony defect.\(^1\)\(^-\)\(^3\) A variety of bone grafts and substitutes are in common use:\(^4\) the patient’s own bone (autogenous bone graft), human cadaveric bone (allograft), or artificial bone graft (synthetic material, other natural substances such as coral). Autogenous bone grafting provides optimal biology, but has the drawbacks of donor site morbidity (pain, hematoma, infection, fracture) and limited availability.\(^5\)\(^-\)\(^6\) On the other hand, allogeneic and artificial grafts are expensive, can be difficult to process, have limited osteogenic or osteoinductive properties, can cause a nonimmune or immune inflammatory response, and can transmit disease.\(^7\)\(^-\)\(^9\) To determine how the development and increasing availability of both allogeneic and artificial bone grafts may have influenced the use of autogenous bone grafts in recent years, the authors studied the use of bone grafts and bone graft substitutes in the United States during a 16-year period to identify trends.

**Materials and Methods**

The Centers for Disease Control and Prevention in Atlanta, Georgia, provided the National Hospital Discharge Survey multiyear data CD. The National Hospital Discharge Survey includes de-identified information only from short-stay noninstitutional hospitals, but not federal, military, or Veterans Administration hospitals.\(^10\) The data contained medical and demographic information on more than an estimated 500 million patients collected from 500 hospitals, reflecting the entire US population. The estimates were based on a sophisticated probability design, taking into account population and other factors. Data were weighted to allow unbiased statistical analyses. The diagnoses and procedures were based on *International Classification of Diseases, 9th Revision, Clinical Modification* (ICD-9-CM).

The institutional review board decided that the study was exempt from approval. The authors identified all patients who underwent either autogenous bone graft, corresponding “excision of bone for graft” in the ICD-9-CM (codes 77.70-77.79), or allogeneic or artificial bone graft, classified as “bone graft” in the ICD-9-CM (codes 78.00-78.09), leaving a cohort of almost 2 million patients. The last digit of the ICD-9-CM code reflected the location. Whenever the source of bone graft was allogeneic or artificial, only the procedure code for “bone graft” (codes 78.00-78.09) was used. For the sake of simplicity, it was called “artificial” in this study. If autogenous bone graft was used, both procedure codes were usually given (“excision of bone for graft” for harvesting [codes 77.70-77.79] and “bone graft” for application [codes 78.00-78.09]), but “excision of bone for graft” was more consistent.

The following demographics were available: sex, year of procedure, age, race, discharge status, geographic region, hospital size based on number of beds, source of payment, and days of care (Table 1).

Years were categorized into 4 groups of 4 (1992-1995, 1996-1999, 2000-2003, and 2004-2007) to simplify the tables and identify trends over longer periods. Considering the large sample size, a normal distribution was assumed for continuous data, which was presented as mean±standard deviation. The Pearson chi-square test was used to determine the \(P\) value that reflected the difference between 2 categoric variables. Data were presented in absolute and relative numbers. Analysis of variance was used to determine the \(P\) value reflecting a significant difference between continuous data for more than 2 groups.

The numbers of autogenous and artificial bone grafts per year were used to show trends in combination with the US population between 1992 and 2007 (Figures 1-2). The relative numbers (n/100,000/4-year period) of autogenous and artificial bone grafts were calculated based on the population provided by the National Hospital Discharge Survey. Chi-square for the linear trend was used to compare the overall trend and the trends for autogenous and artificial bone grafts (Figures 3-4). \(P<.05\) was considered significant.

The 5 most common reasons for bone grafts were determined based on the relative number of distinct ICD-9 codes. The rank and percentages of the diagnoses were shown for each period (Table 2). The authors also defined broader groups of patients with diagnoses treated with autogenous or artificial bone grafts that were based on the ICD-9 codes; 12 groups were formed, and the proportions (n/1,000,000/4-year period) per diagnosis group visualized. The proportion is per 1 million capita (and not 100,000), to provide more meaningful data. The subgroups of the largest group “diseases of the musculoskeletal system and connective tissue” (ICD-9-CM codes 710-739) were shown separately because of the considerably larger numbers of bone grafts in this group compared with the others (Figure 5).

**Results**

Bone grafts were used in almost 2 million patients between 1992 and 2007. Half of them were men, with a mean age of 50 years and a mean of 5 days of inpatient care. The sex of patients undergoing bone grafts significantly changed from predominantly male to predominantly female over time. In addition, mean patient age increased from 47 to 53 years during a period of 15 years (\(P<.001\)). The mean length of stay decreased significantly from 6 to 5 days. The rate of routine discharge to home decreased, whereas the rate of patients discharged to a short-term or long-term-care facility increased significantly (\(P<.001\)). The death rate decreased from 0.6% to 0.2% (Table 1).

The use of grafts decreased in both absolute number and proportion of the total
US population after 1999 for autogenous bone grafts and after 2003 for artificial bone grafts. There was a slight transition from autogenous to artificial bone grafts from the late 1990s to the early 2000s (Figures 1-4).

In all periods, diseases of the musculoskeletal system and connective tissue (ICD-9-CM codes 710.0-739.0), especially spinal diseases (ICD-9-CM codes 720.0-724.9), were by far the largest group or subgroup, respectively. The

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<td><strong>n</strong></td>
<td>60,000</td>
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<td><strong>%</strong></td>
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**Demographic Characteristics of Patients With Artificial and Autologous Bone Graft (ICD-9-CM Code 77.7x and 78.0x)**

Abbreviations: ICD-9-CM, International Classification of Diseases, 9th Revision, Clinical Modification; SD, standard deviation.
main diagnoses among patients receiving bone grafts did not change except for dorsopathies (spinal diseases) and lower-limb fractures. The use of bone grafts in dorsopathies and lower-limb fractures decreased over time (Figure 5 and Table 2). The decrease in dorsopathies was mainly caused by a decreased use of bone grafts in cervical intervertebral disk displacement and cervical spondylosis. Closed proximal tibia fractures were the largest subgroup of lower-limb fractures. The use of bone grafts in this subgroup decreased by almost one-third. Other diagnoses, such as closed femur shaft, supracondylar femur, and calcaneus fracture, also showed a slight decrease.

**DISCUSSION**

The use of bone grafts and bone graft substitutes decreased during the study pe-

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Table 2

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<tr>
<td>722.0</td>
<td>Displacement of cervical intervertebral disk without myelopathy</td>
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<td>1</td>
<td>3</td>
<td>4</td>
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<tr>
<td>733.82</td>
<td>Nonunion of fracture</td>
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<tr>
<td>722.10</td>
<td>Lumbar disk displacement</td>
<td>3</td>
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<td>996.40</td>
<td>Unspecified mechanical complication of internal orthopedic device, implant, and graft</td>
<td>4</td>
<td>5</td>
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<tr>
<td>722.52</td>
<td>Degeneration of lumbar or lumbosacral intervertebral disk</td>
<td>5</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>724.02</td>
<td>Spinal stenosis, other than cervical; lumbar region, without neurogenic claudication</td>
<td>5</td>
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period. The authors believe that several factors may have contributed to this decrease. First, patients and surgeons may be avoiding the additional pain and adverse events associated with obtaining autogenous bone. Freeland and Rehm\textsuperscript{11} reported that up to 39\% of patients who had bone taken from the iliac crest had at least a minor complication. The most common complications noted with bone graft harvesting were persistent pain at the donor site, hematoma, delayed wound healing, and cosmetic deformity at the donor site.\textsuperscript{12} Second, the development of new implants and techniques to treat dorsopathies, complicated fractures, and nonunions made bone grafting unnecessary. Examples are the treatment of distal radius fractures using volar locked plates\textsuperscript{13,14} and the treatment of distal femur fractures with minimally invasive plating.\textsuperscript{15-17} Third, the indication to proceed with alternative surgical (without bone grafting) and nonsurgical treatment may have changed. An example is the treatment of patients with cervical spondylosis or disk displacement.\textsuperscript{18,19}

Several factors should be kept in mind when interpreting the data. First, the study is a retrospective study based on an estimated number of patients obtained from a nationwide sample. The large amount of administrative work made the database prone to possible misclassification and coding errors. However, quality control programs estimated the error rate for data entry of medical (ICD-9-CM) coding and data entry of demographic information each year as less than 0.5\%.\textsuperscript{20} Second, the National Hospital Discharge Survey database allowed the study of comorbidities and in-hospital adverse events. However, the authors could not directly link bone grafting with distinct donor site adverse events on the basis of the available ICD-9-CM codes without access to the medical records because most of these patients had more than the bone graft procedure.

The lesser decrease in the use of bone graft substitutes compared with autogenous bone grafts in the current study might reflect a shift from autogenous to substitute grafts. On the basis of the increasing number of bone graft substitutes on the market, the authors were surprised that the use of these substitutes was decreasing as well. However, current artificial bone grafts may cause lower union rates compared with autogenous bone grafting and nonunion of the graft-host junction. Despite the improved quality and safety standards for processing of musculoskeletal allografts in the last decade, there is still a risk of infection and disease transmission.\textsuperscript{8,21}

The significant increase in patient age was parallel to the increase in the age of the US population.\textsuperscript{22} As a probable further consequence of this change, the rate of older women increased over time in the study population undergoing bone grafting. During the study period, patients tended to be transferred earlier to a short-term or long-term-care facility in an effort both to decrease the duration of the acute care stay and to improve functional recovery, as also seen in other studies.\textsuperscript{23,24}

**Conclusion**

The use of bone grafts in the United States changed during the past 16 years. The absolute numbers and proportions of both decreased significantly, less so for graft substitutes. There was also a significant shift in bone graft recipients toward older age and female sex. Spine procedures account for nearly half of all bone graft procedures, and this has not changed over time. However, during the study period, there was a shift from cervical to lumbar procedures. The use of bone grafts and bone graft substitutes is decreasing in the United States, with a slight shift from autogenous to substitute grafts. The main diagnoses—spine diseases and nonunions—for which bone grafts were used did not change.
REFERENCES


