THE COST-EFFECTIVENESS OF LIMB SALVAGE FOR BONE TUMOURS

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The use of endoprostheses for limb salvage in primary bone tumours is highly specialised. Studies have shown no significant difference in survival, function or quality of life between patients with limb salvage and those with amputation.

We have derived a formula for calculating the ongoing costs of limb salvage with an endoprosthesis which is based on actual costs and uses historical data to show the likelihood of further surgery or revision. Comparative data for amputation are also shown. Using current prices, the cost-effectiveness of surgery with an endoprosthesis is clearly demonstrated.

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Over the last 20 years limb salvage surgery for primary bone tumours has become commonplace throughout the world. About 85% of patients are now offered limb salvage; the remainder have amputation. This trend is due to the use of modern chemotherapy which offers a realistic chance of cure in 60% to 65% of cases. An additional benefit is that it dramatically reduces the risk of local recurrence which almost always results in further metastases and death.

A variety of methods of limb salvage is available, each with advantages and disadvantages. It is possible to save the limb without reconstruction when tumours involve expendable bones such as the fibula, clavicle or ribs. Most primary bone sarcomas, however, arise in the long bones where definitive reconstruction is required. The options available are limited and include allografts, rotationplasty or endoprostheses.

Endoprostheses have been available for a number of years during which considerable experience in their use has been acquired. Data are available regarding their success, function, complications and long-term survivorship. It has been shown that while patients who have limb salvage have a slightly higher rate of local recurrence than those with amputation, the overall survival of the two groups is indistinguishable. In experienced hands, limb salvage does not therefore compromise patient survival when compared with amputation.

Other studies on functional outcome have assessed quality of life in matched groups of patients who have had either amputation or limb salvage. They have failed to show any convincing difference. Patients with amputations may be more physically active than most with limb salvage, but they have a less satisfactory body image. Overall, achievement and satisfaction with the outcome are similar.

For patients with a primary bone tumour the dividing line between limb salvage and amputation is small. Patient (and possibly surgeon) preference will usually lean towards conservation even although it is almost certain that any form of limb reconstruction with a prosthesis will ultimately require further surgery.

Amputation is best avoided if possible and the more proximal the tumour the more relevant this becomes. In 1935 Gordon-Taylor and Wiles described hindquarter amputation as “the greatest mutilation ever performed on the human frame” and there is little difference 60 years later. Exoprosthetic fitting can be achieved but is rarely used. Most patients rely on crutches or a wheelchair. Disarticulation of the hip is similarly disabling and any amputation of the upper limb is devastating. After shoulder disarticulations or forequarter amputations no realistic function can be achieved. In these situations limb salvage is preferable provided that overall survival is not compromised.

Many primary bone tumours, particularly osteosarcoma, occur around the knee; these generate most controversy with regard to limb salvage or amputation.

Our aim was to determine the cost-effectiveness of limb salvage with an endoprosthesis and to compare it with that of amputation.
COST MODEL

Patients with primary bone tumours require similar treatment for their tumour in terms of staging, biopsy, chemotherapy and follow-up irrespective of whether they have amputation or limb salvage. Costs which must be assessed for each procedure include the total cost, the provision of the prosthesis, rehabilitation, maintenance and the management of complications.

For amputation this assessment is relatively straightforward. The cost includes an inpatient stay (A) which can be easily identified. Most limb-fitting centres now offer a ‘package price’ for the provision of an exoprosthesis and maintenance costs for follow-up and attention to complications (B). The cost is therefore A plus the annual cost (B) multiplied by the number of years (y) since the amputation, i.e. (A+By).

For limb salvage with an endoprosthesis costing is more complicated. Many centres now offer a composite cost which is made up of factors related to length of stay, the price of the implant, the complexity of the surgical procedure and rehabilitation (E). Most patients with an endoprosthesis will require follow-up in addition to that needed for the tumour alone. This will vary from centre to centre but on average will consist of two extra outpatient attendances a year. If the cost of each is (F) then the ongoing costs will be 2Fy, where y is the number of years since the operation.

Endoprosthetic replacements will eventually fail and may also require servicing operations such as rebushing. The incidence of failure of prostheses of the distal femur and proximal tibia based on a historical group of patients is now available.\(^{16}\) A rebushing is a relatively simple procedure and the cost of this (S) can be added to the equation with the risk of it being required in any one year (s). The latter can be obtained from life-tables of the risk of rebushing.

A revision procedure is a much greater expense. A new endoprosthesis is normally required, with a much longer stay in hospital. If the patient develops infection there is further delay or the patient may need a two-stage revision procedure. The costs of revision (R) are complex but are similar to those of the primary excision and endoprosthesis. If the risk of a revision is \(r\), then the cost of a revision procedure will be \(rRy\) where y is the number of years since the original operation.

The success of a revision procedure is not yet known. Extrapolating from hip replacements the chances of a successful revision procedure for a certain time period are under half that of the primary procedure.\(^{17}\) The failure rate of a revision is at least two to three times that of the primary procedure, but will only apply to those which have already failed. In the ‘worst-case scenario’ this will be \(3r\).

Thus, the ongoing cost for endoprosthetic replacement is:

\[
E+2Fy+sSy+rRy+3r(rRy)
\]

where:

- \(E\) = the cost of the original procedure,
- \(y\) = the number of years since the original operation,
- \(F\) = the cost of a follow-up attendance,
- \(s\) = the risk of a ‘servicing’ procedure in any year,
- \(S\) = the cost of a ‘servicing’ procedure,
- \(r\) = the risk of a revision procedure being needed, and
- \(R\) = the cost of a revision procedure.

All risk factors are assumed to be constant over a period of years.

To determine the actual costs for a population of patients as opposed to a (surviving) individual, adjustments must be made for the mortality of that group of patients.\(^{17}\) If the mortality of the two groups of patients is considered to be identical, as in this case, then this can be ignored.\(^{11}\)

ACTUAL COSTS

All prices mentioned below are at the time of writing (1997).

Amputation. The cost of an amputation includes the length of stay in hospital, the operative procedure, rehabilitation, physiotherapy and the provision of appropriate prostheses. Data on the actual costs have been obtained from several sources as follows:

1) The cost of an above-knee amputation carried out on the National Health Service (NHS) was calculated by averaging the costs obtained from a number of different hospitals across the country. This figure is £5757 ($US 9442).
2) The Regional Rehabilitation Centre has estimated the cost of an appropriate prosthesis and ongoing maintenance for an otherwise fit 20- to 30-year-old man to be £4705 ($US 7716) recurring.
3) A private company has estimated the cost for the provision and maintenance of artificial limbs for a young active man, including a leg for swimming (but not a ‘sports leg’) to be £14483 ($US 23752) in the first year, 70% of this in the second year, and 30% in the third year. The fourth-year cost is 70% of that of the first year and that of the fifth year is 100%; the cycle then repeats itself. Thus, the total cost over four years is £39104 or £9776 ($US 16033) per annum.

Using the equation given above for an NHS purchaser, the cost will be:

\[
£5757 + 4705y ($US 9442 + 7716y) \text{ where } y = \text{the number of years since the amputation.}
\]

If the artificial limb is provided in the private sector then the cost will be:

\[
£5757 + 9776y ($US 9442 + 16033y) \text{ where } y = \text{the number of years since the amputation.}
\]

Endoprosthetic replacement. The costs of endoprosthetic replacement have been determined on a similar basis from advertised average costs from specialist centres in the UK.

The NHS charges for the cost of the operation (E) including the implant and subsequent inpatient rehabilitation is £12 806. An outpatient attendance (F) to include
radiographs and scans is £120. A servicing procedure such as a rebushing (S) is £1711. A revision procedure (R) is estimated also at £12,806. The risks of rebushing and revision have been taken from work carried out at our own unit (Fig. 1) which broadly estimate the risk of rebushing at 3% per year ($s = 0.03$) and of a revision at 4% per year ($r = 0.04$).

Thus, according to the equation given above for endoprosthetic replacement the total cost will be:

\[ £12,806 + £865 (\text{US} \ 21,002 + 1419) \text{ per annum}. \]

Figure 2 shows the costs for both the NHS and the private sector.

**DISCUSSION**

Nowadays, cost-effectiveness is a significant factor in health care almost everywhere in the world. It is very unusual to find that two such radically different procedures for treating one condition have almost identical outcomes when assessed in different ways. The only other study which discussed comparable costs was that of Scales \(^{18}\) who designed the original Stanmore endoprosthesi.

Early fears that limb salvage surgery would result in an increased rate of local recurrence have not been justified. Local recurrence is now considered to be associated as much with poor risk disease as with less than adequate surgery. Prospects for cure lie with effective chemotherapy rather than with amputation.

Conversely, the assumption that limb salvage surgery would produce a better quality of life has not been substantiated. There will be good and bad results whichever surgical procedure is used and, overall, there is remarkably little difference between the two groups. This is probably a reflection of the resilience of the patients who have survived their cancer be it with a limb or an amputation.

Alternatively, it may well be an indicator of the insensitivity of current methods of assessing the quality of life.

In our study we have used a revision rate which has been averaged over a long time period rather than the actual rate of revision in any one year as was used by Pynsent et al. \(^{17}\) in their study on the total cost of hip replacement. We have calculated the total costs using both methods and have concluded that when the rate of revision approximates to a straight line there are no significant differences between the total figures.

No allowance has been made for comparing how many patients in each group will be able to return to their work or obtain new employment. Previous studies suggest that there is little difference between the two groups. \(^{12-14}\) Similarly, we have not estimated the time away from work because of problems with the limb. Patients with endoprostheses will be away from work if they have further operations or complications. Conversely, those with amputations may also have complications such as discomfort, broken limbs needing repair and stump problems. In addition, some patients will decide never to wear a prosthesis even after an apparently satisfactory above-knee amputation. \(^{19}\)

The surprising feature is the considerable cost of having an amputation. Most active young people will demand and use a sophisticated artificial limb. They will frequently have stump problems and require recasting of the socket. Most will require a spare prosthesis. Many will request and use a sports limb and also a limb for swimming. A new prosthesis will be necessary at regular intervals. With the increasing complexity of artificial limbs it is likely that the cost will go up rather than down.

To measure the failure rate of the endoprostheses we have used figures taken from our own experience; they reflect the failure rate of what should now be considered as first-generation endoprostheses. These were comparatively
primitive by modern-day standards with a knee based on the simple Stanmore hinge. In conventional knee replacements for osteoarthritis these implants have been shown to have a very high failure rate and are not recommended for routine use.\(^{20}\) Unwin et al\(^{16}\) found that the failure rate for aseptic loosening alone in their large series of endoprostheses around the knee was 50% at 20 years which is a failure rate of 2.5% per year. This does not include other causes such as infection and implant failure which are responsible for an extra failure rate of 1.5% per annum.

Modern implants use a rotating-hinge knee with an improved bearing surface and a hydroxyapatite collar. These features should give a significantly lower rate of wear and failure. If the failure rate of modern implants is lower than that of our series then the cost-effectiveness of limb salvage will increase considerably. The high rate of failure of these knee replacements, 4% per annum, must also be placed in the context of the age group under study. The mean age of patients with distal femoral or proximal tibial replacements was 20 years and many were 13 or 14 years old when they had their first prosthesis inserted.

The equations can be used for any method of limb salvage provided that the costs and the risks of failure are known. We know that endoprostheses of the proximal humerus have a very low failure rate even at 20 years (Fig. 1), but comparison of their cost with that of amputation should not be made. Amputation results in such a dramatic loss of function that the small excess cost of limb salvage is readily justified. Similarly, the advantages of replacing the proximal femur compared with a hip disarticulation are usually quite evident.

These figures show that the cost saving for an average patient over a 20-year period will be approximately £70 000 at 1997 prices, that is around six times the cost of the original procedure.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

REFERENCES


