The economics of preventing revisions in total hip replacement

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We showed that the selection of a cost-effective type of cement and method of prophylaxis against deep infections for patients undergoing total hip replacement depended on the number of arthroplasties performed each year at individual hospitals. When 100 arthroplasties were performed each year, the use of Palacos cement and systemic antibiotics reduced the total costs to the department, i.e., the cost of cement, infection prophylaxis and revisions. The use of gentamicin-impregnated cement in combination with systemic antibiotics will further reduce the risk of revision and is another cost-effective strategy. The most effective infection prophylaxis would be achieved with a combination of gentamicin-impregnated cement, systemic antibiotics and surgical enclosure. However, the additional cost of the surgical enclosure would not be offset by cost savings due to reduced risk of revisions.

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Total hip replacements (THR) have been performed for more than 30 years in Sweden. Sweden has a population of about 8.8 million and in 1992–1994, the annual number of primary THR was more than 9,000. The mean age of the operated population was 70 years.

In the early 1970s, THR was associated with risks of deep infections of 5–15 % and loosening of 3–8% (Ahnfelt 1986). However, currently aseptic loosening is the main reason for failure. For implants inserted in 1989 and followed for 5 years, 1% of the patients have undergone revision due to aseptic loosening. The risk of revision due to deep infections for patients with implants from 1989 and 5 of years follow-up has been reduced to below 0.3% (Herberts and Malchau 1997, Malchau and Herberts 1998).

Aseptic loosening or infection associated with THR requires revision. The procedure is costly and often complicated. In cemented THR, the choice of type of cement may affect the risk of aseptic loosening and the risk of deep infection. 6 different types of cement are or have been used in THR in Sweden. The risk of aseptic loosening correlates to the type of cement (Table 3; Herberts and Malchau 1997, Malchau and Herberts 1998).

The prophylactic methods used in Sweden to prevent infections in patients undergoing THR include: parenterally and locally administered antibiotics, surgical enclosure and ventilated suits. Locally administered antibiotics are in the form of cement impregnated with gentamicin. Surgical enclosure and ventilated suits aim to reduce the level of airborne contamination in the operating room. These four methods can also be used in combination.

In making decisions on strategies for primary THR, the health care provider must choose between cement and prophylactic measures to reduce the risk of revision. For this decision, both expected costs and outcomes in terms of the patients' health must be considered. Each type of cement entails an acquisition cost and a risk of aseptic loosening. Prophylactic measures against infection are costly, but if deep sepsis can be prevented, the cost of prophylaxis may be offset by a reduced need for revisions and their subsequent costs.

We calculated the costs of various types of cements and the four methods of prophylaxis used alone or in combination in patients undergoing THR. We aim to determine the point at which the costs are offset by a reduction in the incidence of revision due to deep infection and aseptic loosening.

Methods

The method used is first to estimate the expected health care costs per strategy, i.e., including costs of cement, infection prophylaxis and costs of revisions. Secondly, we are comparing the alternative strategies in order to establish the dominant strategies, i.e., strategies which are more effective and less costly than the alternatives.

The Swedish National Hip Arthroplasty Register offers a good opportunity to study the magnitude of

Table 1. The number of orthopedic departments in Sweden using different combinations of prophylaxis against infection in THR

Prophylactic methods	1979	1985	1995
SA+SE+XS+PC	1	2	3
SA+PC+SE	2	4	20
PC+SE+XS	2	3	1
SA+SE+XS	7	11	2
SA+SE	7	14	10
SA+XS	0	1	0
SE+XS	0	0	0
SE+PC	0	0	0
SA+PC	7	18	46
SE	0	0	0
PC	0	0	0
SA	28	21	5
XS	1	0	0
None of above	0	0	0
Sum	55	74	87

SA systemic antibiotics
PC polymethylmethacrylate cement with gentamicin
SE surgical enclosure
XS exhaust-ventilated suits
Source: The Swedish National Hip Arthroplasty Register

the risks of infection and loosening, and the underlying reasons for reducing these risks (Malchau and Herberts 1998). The register was started in 1979 and consists of data from 148,359 primary operations describing the use of various technologies and methodologies in THR in Sweden. By identifying risk factors for poor outcomes, the register is a valuable instrument for improving hip replacement quality in Sweden.

The types of cement most frequently used in Sweden are: Palacos gentamicin, Palacos, Simplex and CMW. Assuming, on average, 120 g cement per primary operation, the use of Simplex and Palacos gentamicin meant highest costs and the use of plain Palacos meant lowest costs for cemented THR in Sweden, ranging from USD 223 to USD 89 in 1996/1997 prices.

During 1979–1995, the use of prophylactic combinations against infection in THR increased (Table 1). In 1979, most of the departments used systemic antibiotics alone, whereas in 1995, the most frequently used prophylactic measure was a combination of systemic antibiotics and gentamicin-impregnated cement. Since 1985, there has also been a frequent use of surgical enclosures, in combination with parenterally and/or locally administered antibiotics.

The cost of systemic antibiotics (SA) was determined by using data from The Swedish National Hip Arthroplasty Register on the antibiotics given, the dosages, and the durations of treatment. The prices of antibiotics were taken from FASS, 1996 (Läkemedelsinformation 1996). The average cost of systemic antibiotics for the initial operation was USD 17. This is based on an average use of 5 g parenteral Ekvacillin and 2 g peroral Heracillin. Assuming that a nurse performs the treatment at a cost of USD 16, the total cost of this prophylactic measure is estimated at USD 33 (Samverkansnämnden för södra sjukvårdsregionen 1996).

The cost of locally administered antibiotic prophylaxis (PC) was determined by calculating the difference between the costs of standard bone cement and of polymethylmethacrylate cement impregnated with gentamicin. Assuming that 120 g cement was used at each operation, the average extra cost of the initial operation was USD 134 when gentamicin-impregnated cement was used.

Calculating the average cost of the initial operation when a surgical enclosure or ventilated suits were used required that the cost of buying and installing the equipment, as well as the length of its useful life be considered. In all our calculations we will treat the investment as an annuity and assume a real capital cost of 5% a year. The average cost of the initial operation will depend on the number of operations performed.

The average cost of buying and installing a surgical enclosure (SE) was USD 144,000. This cost is based on a surgical enclosure without side-walls. The HEPA-filtered vertical airflow is supplied through a ceiling. Allowing 20 years of use and adding a yearly cost of USD 3,300 for filters, electricity and maintenance, the total annual cost was USD 16,400. When 100 operations were performed each year, this method of prophylaxis costs about USD 164 for each initial operation. (According to the producer, the surgical enclosure has 40 years of useful life, which means an annual cost of USD 13,300 and a cost of USD 133 per operation.) It should be noted that the enclosure will probably be be used in surgical procedures other than THR. The average cost of each initial operation will depend on the number of operations performed, on the assumed number of years of use and capital costs.

The average cost of exhaust-ventilated suits (XS) for each initial operation consists of an investment cost for special equipment and of buying and laundering the exhaust-ventilated suits. Assuming the equipment has 10 years of useful life, the annual cost was USD 2,164. Each new suit costs USD 410. Assuming each suit had a useful life of 300 operations and that the surgical team used four suits for each operation, the average cost of each initial operation was USD 6. Laundry costs of each initial operation for four suits were USD 45. When 100 operations were performed each year, the cost of this prophylactic method was USD 72. This estimate was based on a study by the

Table 2. Average cost (USD) in 1996/1997 of prophylaxis of initial arthroplasty, depending on the method of prophylaxis and number of operations performed each year

Method of prophylaxis	No. of arthroplasties performed annually 50	100	150	200	250
SA+SE+XS+PC	589	403	341	310	291
PC+SE+XS	556	370	308	277	283
SA+PC+SE	495	331	276	249	232
SA+SE+XS	455	269	207	176	157
SE+PC	463	298	243	216	200
SE+XS	423	236	175	143	125
SA+SE	361	197	142	115	98
SA+PC	166	166	166	166	166
SA+XS	126	105	97	94	92
SE	329	164	110	82	66
PC	134	134	134	134	134
XS	94	72	65	61	59
SA	33	33	33	33	33

Abbreviations, see Table 1.
Source: Own calculations

Table 3. The risk of aseptic loosening in osteoarthrosis, correlated to the type of cement and the cost of cement per operation (1996/1997 prices)

	Aseptic loosening in osteoarthrosis Risk ratio	Cost per primary hip replacement (USD)
Type of cement		
Sulfix	1.00	[a]
Simplex	0.58	205
CMW	0.68	145
Palacos	0.53	89
Palacos gentamicin	0.48	223

[a] not available on the Swedish market in 1997
Source: Malchau and Herberts (1998)

Swedish Planning and Rationalization Institute of Health and Social Services in 1980. The 1980 figures have been increased to approximate 1996 prices by use of a net price index (Spri 1981).

The costs of prophylaxis varied with each prophylactic method and with the number of initial operations performed each year (Table 2). Systemic antibiotics alone invariably cost less in each initial operation than any other method, regardless of the number of operations performed each year.

The risk of aseptic loosening

Using a multivariate Poisson model, Malchau and Herberts (1998) have analyzed the risk of aseptic loosening, correlated to the type of cement (Table 3). Plain Palacos and Palacos gentamicin had the best performances.

The incidence of deep infections

Figure 1 shows the incidence of deep infections (within 5 years of follow-up) for about 120,000 pri-

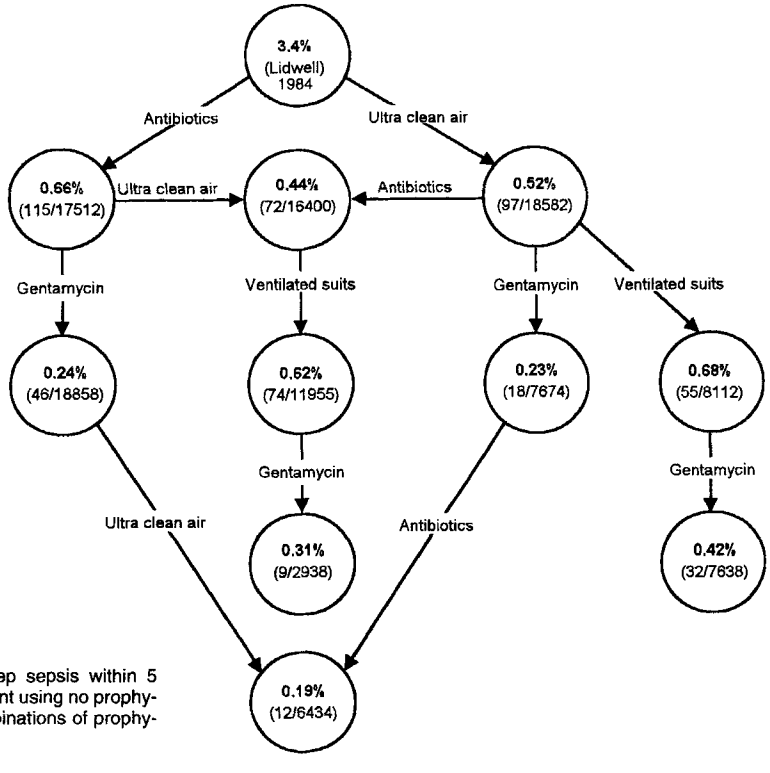

Figure 1. Incidence of deep sepsis within 5 years of total hip replacement using no prophylaxis and with various combinations of prophylactic methods.

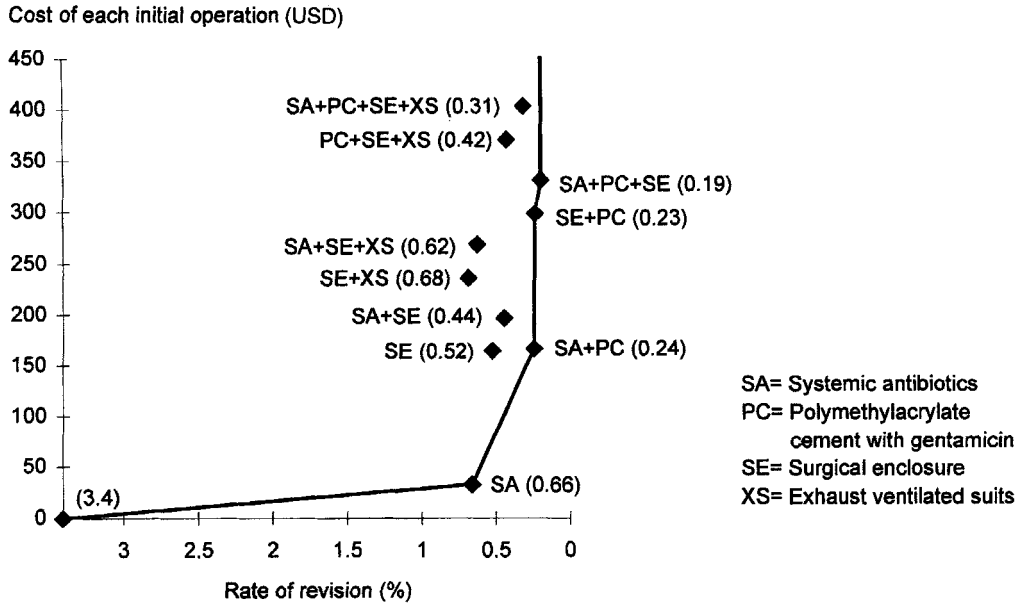

Figure 2. Cost of prophylaxis with various rates of infection, 1996/1997 prices.

mary operations registered in Sweden between 1979 and 1990/91. The incidence of deep infections when no prophylactic measure was used is based on the findings of earlier studies (Lidwell 1984). The lowest incidence of deep infections is achieved with a combination of systemic antibiotics, gentamicin-impregnated cement and a surgical enclosure. Figures 2 and 3 show the cost of each initial operation when using prophylaxis associated with various rates of infection. Note that the costs of surgical enclosure and exhaust-ventilated suits are based on 100 initial operations a year.

Cost of revision

The majority of patients with aseptic loosening or prosthetic infections must undergo a new operation. Average cost of revision includes expenditure on the number of days in bed on orthopedic, isolation, and postoperative wards; on anesthesia, blood, prostheses, radiographic examination, and other tests; and on medical treatment and drugs before and after operation. Expected costs of operation and the treatment of postoperative complications should be added to the cost of cement and infection prophylactic measures of the primary hip arthoplasty in order to determine the total cost attributed to deep infections and aseptic loosening. Our calculations are based on the average cost of primary THR and revision at Sahlgrenska Hospital in Göteborg, 1996/1997. The average cost of a primary THR was USD 8,800. The average cost of a one-stage revision was USD 11,700, i.e., about 1.3 times the cost of a primary THR (Personal communication, administrative office, Sahlgrenska Hospital). We assume that the average cost of a two-stage revision was twice the cost of a primary THR, i.e., USD 17,600. It is to be noted that costs for postoperative complications are not included in these figures. According to the National Hip Arthroplasty Register, about half of the patients with a deep infection had a one-stage surgical repair and half of the patients had a two-stage surgical repair during the period 1978–1994. A weighted average cost of revision could be estimated as USD 14,700. Note that the cost of revision varies between settings and each hospital has to use their own calculations.

Results

Comparisons of prices and performances of the various types of cements indicate that plain Palacos provides the best reduction in the risk of aseptic loosening in relation to its cost. Sulfix, Simplex and CMW all provide a higher risk of aseptic loosening at a higher cost than plain Palacos, i.e., they are not cost-effective choices. Palacos gentamicin is the only type of cement with a lower risk of aseptic loosening than plain Palacos but, on the other hand, the cost is substantially higher. Even though plain Palacos is the most cost effective choice of cement with respect to aseptic loosening it will not certainly be the most cost-effective choice of cement if we consider the two

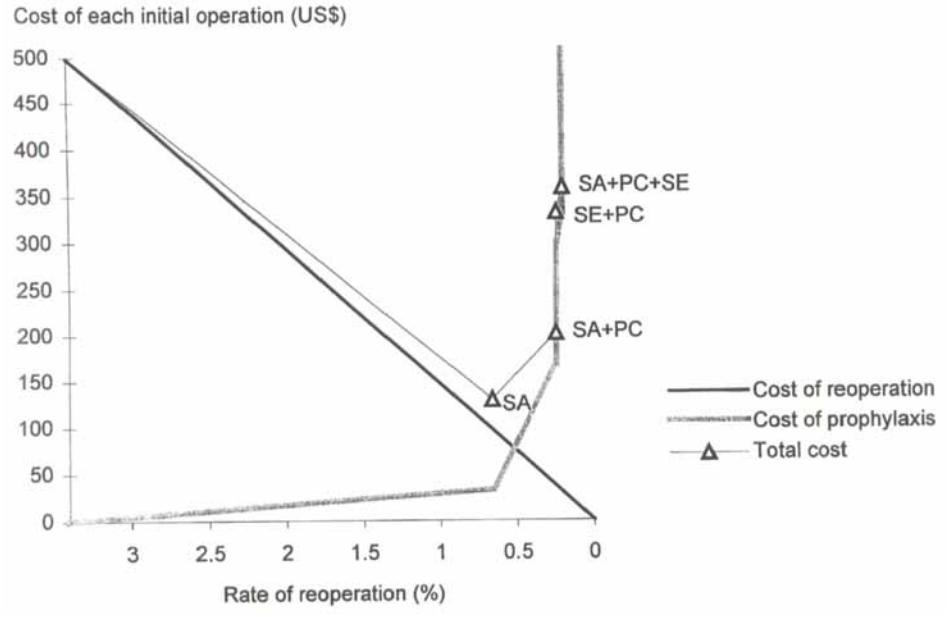

Figure 3. Total cost of deep infection with various rates of infection, 1996/1997 prices.

main risks of revision, i.e., those of aseptic loosening and of deep infection. Therefore, an economic evaluation of the choice between plain Palacos and Palacos gentamicin must consider the risk of deep infection.

Figure 2 shows the cost and effectiveness of the four prophylactic methods and combinations of them for reducing the risk of deep infections when 100 operations are performed each year. Note that it is not the most expensive combination (i.e., a combination of systemic antibiotics, surgical enclosure, exhaust-ventilated suits and gentamicin-impregnated cement) that is the most effective. The most effective prophylaxis is achieved with a combination of systemic antibiotics, gentamicin-impregnated cement and surgical enclosure. This combination of preventive measures has a revision rate due to infection of 0.19% and an average cost of prophylaxis of USD 331 per primary hip replacement.

In Figure 2, the cost-effective methods take the form of a frontier. Methods to the left of the frontier are not cost effective, i.e., the rate of revision could be achieved for less cost by using another prophylactic method. For example, both a surgical enclosure and the combination of systemic antibiotics and gentamicin-impregnated cement cost about USD 163, but they have different effects on the rate of revision. The first alternative gives a revision rate of 0.52%, while the second alternative gives a revision rate of 0.24%.

It should be noted that in all cases when exhaust-ventilated suits are added to another prophylactic measure or a combination of other prophylactic measures, the rate of revision increases. Therefore addition of ventilated suits can never be justified as an effective measure.

In Figure 3, the straight line shows the relation between cost of revision and the rate of revision for a department performing 100 THR a year. If no prophylactic measure is used, the rate of revision is 3.4%. With an average cost of revision of USD 14,700, this corresponds to an expected cost of revision of USD 499. Since there is no cost of prophylaxis, this is the total cost of deep infection. If the prophylactic measure is systemic antibiotics, the rate of revision is 0.66%. This corresponds to an expected cost of revision of USD 97 (USD 14,700 × 0.66%). The cost of prophylaxis is USD 33 (from Table 2) and by adding the expected cost of revision we get a total cost of deep infection of USD 130 (USD 97 + USD 33). Another alternative prophylactic measure is the use of systemic antibiotics in combination with gentamicin-impregnated cement. This option has a rate of revision of 0.24%. The expected cost of revision is USD 35 and for a department performing 100 THR annually the cost of prophylaxis is USD 166. This means that a deep infection costs USD 201.

The expected total health care cost of a deep infection was minimized at a rate of revision of 0.66%. This means that if 100 primary THR are performed each year the hospital department could minimize their total costs of infection prophylaxis and their costs of revision related to deep infection simply by providing plain Palacos and systemic antibiotics. As

shown in Table 2, the cost of using a surgical enclosure decreases as the number of operations performed each year increases. However, 310 or more operations must be performed each year to minimize costs of prophylaxis and deep infection by using plain Palacos and a surgical enclosure.

Discussion

Our analysis indicates that the cost-effective choice of cement with respect to aseptic loosening is plain Palacos or Palacos gentamicin. However, to reduce the risk of complications, not only the risk of aseptic loosening but also the risk of deep infections is important. There are at least four different prophylactic measures, and combinations of them. The four methods analyzed in this study are: systemic antibiotics, local antibiotics, i.e., polymethylmethacrylate cement with gentamicin, surgical enclosure and exhaust-ventilated suits.

There is no overall strategy that can be justified by our economic analysis. The most effective strategy, i.e., the strategy which is expected to result in the lowest risk of deep infections-includes a surgical enclosure. However, the cost-effectiveness of different strategies depends on the number of operations performed each year. The average cost of prophylaxis with surgical enclosure decreases with the number of operations performed. Therefore, the surgical enclosure would provide a competitive alternative only for large orthopedic departments.

In our economic analysis, based on Swedish cost estimates, a department performing 100 THR a year using combinations of plain Palacos and systemic antibiotics will minimize the total cost of prophylaxis and costs of revisions related to deep infection. An alternative strategy, the use of gentamicin-impregnated cement in combination with systemic antibiotics, will further reduce the risk of revisions. However, the total costs for cement, infection prophylaxis and revision will increase. If the population of potential THR patients are risk-averters, it seems likely that they would be willing to pay this amount.

With a third alternative, a health-care provider could add surgical enclosure to the combination of systemic antibiotics and gentamicin-impregnated cement which would result in an even lower risk of revisions. All three strategies can be considered cost-effective. The latter strategy, addition of the surgical enclosure to the combination of systemic antibiotics and gentamicin-impregnated cement, will increase the cost of prophylaxis by USD 164 and the subsequent decreased cost of revision can be expected to be USD 7. The net cost increase would be USD 157. In this case, the question is whether the taxpayer/insured individual/patient is willing to pay this extra amount of USD 157 to reduce the risk of deep infection by 0.5 per thousand. In other words, this means they have to pay USD 314,000 in order to avoid one deep infection ((157/0.5) × 1000). Our analysis gives no answer to this question but we think it should be discussed by the decisionmakers if these USD 314,000 could be used for other purposes and result in better value for this money.

However, it should be noted that for a large department that is performing 250 THR annually, the incremental cost for adding the surgical enclosure to the combination of systemic antibiotics and gentamicin-impregnated cement will only result in an increase of USD 66 to the cost of prophylaxis. The incremental costs of surgical enclosures decreases with the number of operations performed and therefore it would be best to make investments in surgical enclosures for large orthopedic departments.

In 1995, most orthopedic departments in Sweden used cost-effective combinations of prophylactic measures. 71 of 87, i.e., about four-fifths, of the orthopedic operating rooms used one of the three cost-effective strategies described above. The commonest prophylactic measure was a combination of systemic antibiotics and gentamicin-impregnated cement. All except one department used systemic antibiotics alone or in combination with other prophylactic measures. None of the departments used exhaust-ventilated suits alone.

It should be noted that in most practices, the use of plain versus gentamicin-impregnated Palacos is most probably based on a general decision made in each individual department. However, Palacos with gentamicin is almost always used in higher-risk patients, whereas other types of cement are often used in lower-risk patients. Higher-risk patients will naturally have a higher revision rate and, as a consequence, we may have underestimated the benefits of using Palacos with gentamicin.

The prophylactic methods against infections have been studied in an earlier economic analysis from Sweden (Persson et al. 1988). This was based on data available at the end of that decade and does not include an analysis of the choice of cement and the risk of aseptic loosening. However, from both that study and the current analysis it can be seen that the more expensive the method of prophylaxis the lower the incidence of deep infections and the subsequent rate of revisions.

The data on costs of cement, prophylactic measures against infections and revisions used in this study are

specific to Sweden. The conclusions to be drawn from the analysis may, therefore, be slightly different for other countries and even for specific settings. The model, however, is general and can be used by any hospital department to calculate the most cost-effective method of preventing complications due to aseptic loosening and deep infections in patients undergoing THR. Various local options can be analyzed by supplying the model with general information. If the relative cost of cement, prophylaxis against infections and revisions are the same as the ones we have calculated, the conclusions will be the same as ours. When estimating the incremental costs for the various prophylactic methods, estimates should be based on the total number of arthroplasties, provided that the costs of reoperating on the knee and the hip are the same.

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