Revision total knee arthroplasty (TKA) is a complex procedure which carries both a greater risk for patients and greater cost for the treating hospital than does a primary TKA. As well as the increased cost of peri-operative investigations, blood transfusions, surgical instrumentation, implants and operating time, there is a well-documented increased length of stay which accounts for most of the actual costs associated with surgery.

We compared revision surgery for infection with revision for other causes (pain, instability, aseptic loosening and fracture). Complete clinical, demographic and economic data were obtained for 168 consecutive revision TKAs performed at a tertiary referral centre between 2005 and 2012.

Revision surgery for infection was associated with a mean length of stay more than double that of aseptic cases (21.5 vs 9.5 days, p < 0.0001). The mean cost of a revision for infection was more than three times that of an aseptic revision (£30 011 (SD 4514) vs £9655 (SD 599.7), p < 0.0001).

Current NHS tariffs do not fully reimburse the increased costs of providing a revision knee surgery service. Moreover, especially as greater costs are incurred for infected cases. These losses may adversely affect the provision of revision surgery in the NHS.

Total knee arthroplasty (TKA) is one of the most common orthopaedic procedures performed in the National Health Service (NHS)\(^1\) and is recognised worldwide as one of the most cost-effective operations, providing reliable pain relief and an improved quality of life.\(^2\)\(^-\)\(^4\) It is, therefore, no surprise that the number of primary hip and knee arthroplasties undertaken has been increasing globally, resulting in an increased revision burden.\(^5\)\(^,\)\(^6\)

Revision TKA is a complex procedure which carries both an increased risk for the patient and an increase in costs for the treating hospital.\(^7\) The presence of defects of bone and soft tissue and/or infection makes for surgery which is technically more demanding for the surgeon and increases physiological stress for the patient. This has been shown to result in a higher rate of complications, prolonged operating time, greater blood loss and an increased length of hospital stay.\(^8\)\(^,\)\(^9\) Outcomes from revision TKA, both clinical and functional, tend to be poorer, with an increased incidence of pain and instability and a lower quality of life when compared with primary TKA.\(^10\)\(^,\)\(^11\) As well as the increased length of stay, other expenses include peri-operative investigations, blood transfusions, surgical instrumentation and implants.\(^7\)\(^,\)\(^12\) Clearly, providing a revision arthroplasty service results in greater costs for the treating hospital, thereby reducing its profitability.

National Joint Registry (NJR) data have shown a 92% increase in the number of revision TKAs undertaken in the UK over the last five years. A total of 6009 were carried out in 2012: infection accounted for 23% of these.\(^13\) This trend is a global phenomenon: with an estimated 3.48 million TKAs to be undertaken annually in the United States by the year 2030.\(^14\) This upward trend is reflected in other countries, with supporting data in Nordic and Australasian registries.\(^4\)\(^,\)\(^15\)

Not only is the number of revision procedures rising, their associated costs are also increasing: the cost of some procedures now reach £75 000 per patient.\(^7\)\(^,\)\(^13\)\(^,\)\(^16\) Current reimbursement on the basis of the NHS tariff lies between approximately £8795 and £12 490 per revision case.\(^7\)\(^,\)\(^12\)\(^,\)\(^16\)\(^,\)\(^17\) This figure depends on whether the surgery is elective or unplanned, the presence of comorbidities and complications, the length of hospital stay and a unique figure for an individual hospital's market forces factor.\(^17\)

Our primary hypothesis for this study was that revision costs and a longer hospital stay would vary depending on the indication for
revision, with revision for infection having higher costs and a longer hospital stay than revision for aseptic causes, as has been shown by other studies.\(^7\)\(^12\)

Our secondary hypothesis was that the current level of reimbursement is insufficient to maintain a revision knee service.

**Patients and Methods**

We examined inpatient hospital data from 384 revision TKAs at a tertiary referral centre and identified 168, undertaken between 2003 and 2012, which had complete financial data available.

All procedures were performed by one of three arthroplasty surgeons. We excluded any patient who underwent further surgery, such as wound debridement +/- exchange of liner, reduction of a dislocated liner, manipulation under anaesthesia and arthroscopic washout and debridement for suspected infection within four weeks of the index procedure. Patients undergoing conversion of a unicompartamental knee arthroplasty to a TKA and those with incomplete clinical or financial data were also excluded. This left single-stage revision TKA, stage one-of-two revision TKA, and stage two-of-two revision TKA as the only eligible procedures. Stage two of a two-stage TKA for infection was regarded as an ‘aseptic revision’. Demographic and clinical data, including the indication for revision and length of hospital stay, were recorded.

**Costs.** Financial data were collected from patient-level information and costing systems (PLICS). These were introduced in 2009 by the Department of Health to improve the quality of cost data submitted by hospitals.\(^18\) They are collated by trusts on an individual patient basis and include the cost of implants, materials and augments, the use of operating theatres and recovery, ward care during inpatient stay, physiotherapy, occupational therapy, pharmacy, radiology and laboratory studies. For operations undertaken before 2009, inpatient costs were collected from patient records using the same parameters and calculated on a per case basis by our Department of Finance.

**Reimbursements.** For patients who underwent revision TKA after 2009, the reimbursement per patient was available from the PLICS system. This figure included the tariff for the specific patient and automatically adjusted this for length of hospital stay, comorbidities and complications, as well as a including ‘market forces factor’ in the final figure. This factor is additional to the basic compensation per procedure, and is a fee for which the hospital is eligible in return for providing a specialist service, the exact amount varying according to the particular hospital. The factor accounts for variation in ‘unavoidable costs’ in a specific hospital relative to other hospitals such as non-medical staff, medical staff, lands and buildings. For our hospital from 2013 to 2014, the market forces factor was 1.2976.\(^18\) For example, if our hospital had undertaken 100 units of activity at a cost per unit of £500, the total reimbursement would have been 100 x 500 x 1.2976 = £64 880.

A breakdown of the possible tariffs for ‘major knee procedures for non-trauma’ is given in Table I.

For patients who underwent surgery before 2009, the tariff varied depending on the year of admission and was pegged to the appropriate rate for payment by results (PbR), which is the payment system in England under which the Department of Health pay healthcare providers for each patient seen or treated, taking into account the complexity of the patient’s clinical needs. Before 2007, the NHS tariff for 2007 to 2008 was used and adjusted by subtracting the rate of inflation from the 2007 price year on year. After calculating the year-specific tariff for all patients before 2009, this figure was adjusted by factoring in the market forces factor for that year and the length of stay based on the PbR figure of £239 per day.

Unlike the PLICS-level data, pre-2009 data are a calculation rather than an exact figure for reimbursement and may vary from the true figure. As the method of calculating costs and reimbursement varied depending on whether PLICS or a manual calculation of financial data from the notes was used, there were some cases of the latter in which key elements required to make a full calculation of cost were missing. We were, therefore, unable to include these patients in our final analysis (n = 216). Nonetheless, patients in our final analysis are comparable demographically with NJR data\(^13\) and are representative of our patient series as a whole. Descriptive analysis of data was then performed on cohorts based on the indication for revision surgery.

**Statistical analysis.** Patients were divided into aseptic and septic groups: comparisons made between them using a two-tailed unpaired \(t\)-test performed at the 95% confidence level (\(p < 0.05\)). Statistical analysis was undertaken using Prism version 6 (GraphPad, La Jolla, California) and \(p\)-values are presented to three decimal points. Data are presented as bar plots of the means and their standard deviation (SD).
Results

Complete clinical, demographic and financial data were available for 168 patients who underwent revision TKA between 2005 and 2012 and met our inclusion criteria. Their mean age was 65.6 years (32 to 85; SD 2.93): 77 (46%) were male and 91 (54%) female. In the aseptic group, the indications for revision included pain of unknown origin, instability, loosening and periprosthetic fracture (Fig. 1). A total of 45 patients underwent revision for infection and 123 for aseptic causes. All patients with infection underwent a two-stage procedure. Demographic data and findings by indication are summarised in Table II.

The mean length of stay was significantly higher for those undergoing revision for infection (21.49 days; 2 to 43; SD 3.062) than for the aseptic group (9.56 days (1 to 19; SD 0.71) (p < 0.0001, unpaired t-test, (Fig. 2)). The mean total cost was significantly higher for those undergoing revision for infection (£30 011; SD 4514) than in the aseptic group (£9655; SD 599.7; p < 0.0001, unpaired t-test, (Fig. 3)). The mean reimbursement for all procedures was £15 887.65 (SD £21 369) per patient.

The total cost to our hospital of carrying out this work over a period of eight years was £2 669 125.20. This was calculated from the sum of the total number of patients multiplied by the mean cost of £15 887.65 per patient (SD £21 369). The total reimbursement was £1 902 096, which equates to a shortfall of more than £767 029.20 using the latest PbR figures. If averaged out over 168 cases, this reveals a loss of £4565.65 per case.

Discussion

The mean age of patients in this study was 65.6 years, 54% being women. These demographics are similar to those reported by the NJR (mean age 69.5 years, proportion of women 51%). The frequency of revision TKA for infection was 26% (n = 45) and is comparable with that reported in the ninth report of the NJR (23%).13 The highest cost was for an elective revision TKA for infection, which resulted in total hospital costs of £154 000. Of this, £41 200 was attributed to length of stay on the basis of a cost of £400 per 24-hour stay and a total stay of 103 days.19 The lowest cost was for an elective single-stage revision TKA for aseptic loosening of a tibial component with an uncemented prosthesis and a length of stay of five days, which cost £4613.

The mean loss of £4565.65 per patient is significant, but would probably have been higher in a lower volume centre,
not located in central London, where there is a larger market forces factor applied to tariffs.

Patients requiring revision TKA are often frail and elderly, with multiple comorbidities and may be acutely unwell as a result of an infected prosthesis, as well as presenting with confounding factors such as bone loss, joint instability and deformity. These patients require technically more complex surgery with a longer operating time, greater blood loss and a higher rate of complications. In more complex surgery with a longer operating time, greater instability and deformity. These patients require technically more complex surgery with a longer operating time, greater blood loss and a higher rate of complications. In turn this leads to an increased length of stay, morbidity and increased and mortality compared with that experienced by patients undergoing primary TKA. Therefore, revision knee surgery, for any reason, is associated with increased costs. Our data clearly show a discrepancy between the cost of providing a revision knee service and the level of reimbursement, given the current national tariff: this discrepancy is most pronounced when the indication for revision surgery is infection.

Our findings support previous studies demonstrating that revision procedures are associated with a considerably greater cost to the providing hospital, and that these costs are greatest in infected cases. Most studies have attributed this increased cost to longer operating time, perioperative tests and the need for patient optimisation (correction of reversible comorbidities, blood transfusion, and anaesthetic assessment), increased length of stay and the greater cost of revision implants and equipment. Specifically, infection is associated with an increased length of stay and investigations, which, along with medication, antibiotic-eluting spacers and custom implants, all contribute to the higher cost.

The change in the rate of reimbursement for revision TKA from the period of study to the present day is shown in Table III. The annual increase in tariff over the period of study averaged 2.8%, whereas the mean annual rate of inflation based on European Union data for the UK equalled 3%. Although national tariffs are increasing, they remain substantially below the level of costs incurred for providing a revision arthroplasty service. Tertiary referral centres which carry out high numbers of revision procedures will inevitably incur increased costs to their respective trusts, and will find that NHS reimbursement is progressively inadequate.

Part of this funding gap must be filled by an increase in the tariffs, however, there are cost savings that can be addressed by both hospital and surgeon. For example, although most of the cost incurred within the first two days in hospital is attributable to theatre costs, the subsequent inpatient costs vastly exceed this. Consequently, initiatives already in place, such as fast-track surgery and enhanced rehabilitation, are improving the rate of recovery after revision TKA, reducing the length of hospital stay and associated costs. Further savings are also possible if the NHS purchases operating equipment as a network, rather than hiring in equipment on an individual basis when needed. The recent proposal of a network of specialist orthopaedic hospitals responsible for revision and complex arthroplasty surgery would provide a mechanism for this to take place, as well as potentially reducing the rates of infection after TKA.

Several studies from the United States and Europe have also shown a growing discrepancy between costs and reimbursement for primary and revision TKA. With the continuing economic downturn, health budgets are to be reduced further, with £20 billion in budget cuts needed within the NHS over the next few years. This will add pressure to already strained hospital finances.

The limitations of this study are that the analysis focused on the direct costs associated with the initial hospitalisation and did not include further re-admissions for complications; nor did it consider the medical and social costs to the patient and society. It is a financial analysis based on hospital costs and aimed at highlighting the inadequate NHS tariff rate for revision TKA. In addition it used data from a single tertiary referral centre, which may have treated a more complex and varied caseload than that seen in smaller units. It is also acknowledged that while every effort was made to represent the financial data as accurately as possible, the true costs incurred from the admission of a patient are difficult to capture, even when using a centralised, patient-specific method of costing such as PLICS. This will have been amplified somewhat by patients who were included in the study but treated before the implementation of the PLICS system. Therefore, although an accurate calculation has been made, it will not be an absolute reflection of the direct costs for every patient.

Nonetheless, our sample size was adequate and differences in mean outcomes between subtypes were statistically significant. Furthermore, the distribution and indications for revision were similar to those reported in national joint registry data. Therefore, we are confident that the costs incurred by our institution can be applied nationally. If our mean deficit of £4565.65 per case is used, then the overall financial loss to hospital trusts for the 6099 revision TKAs carried out in the UK in 2012 can be estimated to have been £27.4 million.

In conclusion, we accept both our hypotheses, firstly, that revision TKA for infection carries with it a greater cost and a longer stay than that for aseptic indications, and that

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Table III. NHS tariff for elective revision knee arthroplasty by year
the current levels of NHS reimbursement are inadequate for centres which offer a revision knee service.

Author contributions
R. Kallala: Study design, Study implementation, Refinement of the study protocol, Approved the final manuscript.
M. Ibrahim: Study implementation, Refinement of study protocol.
S. Sarmah: Study design, Study implementation, Refinement of the study protocol, Approved the final manuscript.
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No benefits in any form have been received by the authors from a commercial party related directly or indirectly to the subject of this article.
This article was primary edited by J. Scott and first proof edited A. Ross.

References