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REVIEW

Navigation knee replacement

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Abstract Total knee replacement (TKR) achieves an immediate and exceptional restoration in the quality of life that is comparable only to a few other procedures. It has been suggested that the most common cause of revision TKR is error in surgical technique, from malpositioning of the components which results in a poorer post-operative outcome. Based on the theoretical assumption that the use of computer-assisted systems (CAS) in TKRs may improve implant alignment and thus implant longevity, the use of this technology is becoming increasingly popular. This article (a) reviews whether computer-assisted TKR (CASTKR) results in improved prosthesis alignment compared with the conventional technique, (b) assesses the functional and clinical outcomes of CASTKR and (c) evaluates the cost-effectiveness of using this technology.

Résumé La prothèse totale du genou (TKR) permet de restaurer une qualité de vie comparable à peu d'autres techniques. Il est courant de penser que la cause la plus habituelle de reprise des prothèses du genou est secondaire à une erreur technique du fait d'un mauvais positionnement des composants. Sur le plan théorique, l'utilisation de la navigation (CAS) permet d'améliorer l'alignement des implants et donc la longévité de la prothèse. Cette technique devenant de plus en plus populaire. Cet article permet d'analyser les résultats en fonction de l'utilisation de la navigation comparée à une technique conventionnelle, avec évaluation clinique, fonctionnelle (CATKR) ainsi que le rapport coût/utilité de cette technique.

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Introduction

Total knee replacement (TKR) represents one of the most significant advances in orthopaedic surgery in the twentieth century and ranks as one of the most revolutionary advances in modern medicine [26, 28]. It achieves an immediate and exceptional restoration in the quality of life that is comparable only to a few other procedures [10, 31]. It is estimated that 20% of the UK population is now over 60 years old and at least 2% will have significant knee symptoms warranting a knee replacement [40]. In the USA, the demand for primary total knee arthroplasties is projected to grow nearly sevenfold to almost 3.5 million procedures over the next 20 years [19].

TKRs are conventionally performed with the use of intramedullary or extramedullary alignment guides and achieve a high rate of success [32]. It has been suggested that the most common cause of revision total knee arthroplasty is error in surgical technique [38], from malpositioning of the components which results in a poorer post-operative outcome. Based on the theoretical assumption that the use of computer-assisted systems (CAS) in TKRs may improve implant alignment and thus improve implant longevity, the use of this technology is becoming increasingly popular [29].

Computer-assisted or navigation systems fall broadly into two categories: (1) image-based which rely on the data acquired from pre- or intra-operative imaging from modalities such as computed tomography (CT) or fluoroscopy and (2) image-free which require the intra-operative registration of certain key anatomical points which determine the mechanical alignment of the tibia, the femur and the lower limb, and hence define the site of the bony cuts required for implant placement [29].

This article (a) reviews whether computer-assisted TKR (CATKR) results in improved prosthesis alignment compared with the conventional technique, (b) assesses the functional and clinical outcomes of CASTKR and (c) evaluates the cost-effectiveness of using this technology.

Alignment

In knee arthroplasty, restoration of the mechanical alignment is considered to be of paramount importance to allow optimum load sharing and prevent eccentric loading through the prosthesis [44]. It is well established that malalignment of either the tibial or femoral components is associated with loosening, instability and early implant failure [1]. However, the extent of malalignment below which good clinical results are expected is not known [21]. Many studies have shown that placement of components within ±3° of the mechanical axis reduces the risk of early loosening [1, 5, 11] whilst other studies have shown this threshold to be higher [14, 21, 41].

Based on the assumption that the accuracy of computer-assisted devices is between 1 and 2° proponents of CAS believe that computer navigation reduces the risk of malalignment in TKR [18, 45]. Although many studies have confirmed this theory [1, 3, 9, 24, 39], others have shown that there is no difference in orientation or alignment of the femoral or tibial components than that achieved by conventional methods [12, 22, 23, 42]. When evaluating the published reports on navigation knee arthroplasty, two important factors limit comparisons among clinical series. Firstly, there is an absence of an established criterion to define acceptable component alignment, i.e. within ±3°, within ±4° or ±5° [2]. Secondly, it remains unknown if the small differences in observed component alignment affect subsequent clinical outcome [2, 35, 36]. The benefit of computer-assisted devices probably lies in reducing the outliers defined by the post-operative malalignment greater than ±3° in tibial or femoral components or mechanical leg axis [6].

Functional outcome

One study has shown that computer-assisted TKR using the medial parapatellar approach is associated with a delayed recovery of the quadriceps during early post-operative rehabilitation because of the additional quadriceps dissection required to place the femoral tracking array [43]. Quadriceps dysfunction following computer-assisted TKA was most pronounced from days two to five and became insignificant after day five. Although this did not result in increased hospital stay, it could potentially delay discharge in surgical units where an accelerated discharge protocol is used [43].

There is no significant difference in post-operative pain, range of motion, stiffness scores or patient satisfaction scores between computer-assisted and conventional TKRs, up to two years post-surgery [35, 36, 39]. In fact, Spencer et al. (2007) showed that despite the better alignment achieved with the computer navigation technique in their series, they did not find any significant difference in functional outcome at a two-year follow-up [37]. It remains to be seen whether the marginal improvement in alignment with CAS would translate to better long-term clinical outcomes.

Complications

Blood loss

The breaching of the medullary canal using intramedullary jigs during conventional TKR is postulated to cause significant blood loss during conventional TKR [5]. Although some authors have shown that blood loss and transfusion rates are significantly reduced when navigation is used [4, 16], others have refuted this finding and shown that there is no significant difference in blood loss following computer-assisted or conventional knee replacements [17, 38].

Embolic events

Conventional TKRs using intramedullary jigs can potentially cause fat embolism due to elevated intramedullary pressures generated by the alignment rods [30, 34]. One study comparing computer-assisted knee arthroplasty with the conventional technique observed a higher rate of acute post-operative confusional state with the conventional technique [5]. This was attributed to transient hypoxia caused by fat embolism although none of the patients suffered any long-term sequelae.

The risk of fat embolism during knee replacement has been shown to be significantly reduced when an extra-medullary femoral alignment guide [27] or computer-assisted surgery is used [7, 15]. Studies using non-invasive [15] and invasive monitoring [7] have shown that significantly fewer emboli are detected in the systemic circulation during computer-assisted TKR compared with conventional TKR. However, most studies comparing these two methods have not shown any significant difference in post-operative thromboembolic events [2].

Other complications

Potential complications specific to the use of computer-assisted knee replacements include fracture of the tibia or femur due to the fixation of the reference arrays [20] and technical failure such as drill and pin breakages [13, 25]. However, these complications have not been shown to occur to any significant level [2, 5, 12, 33]. Furthermore, although CASTKRs increase the duration of surgery significantly by between 15 and 17 min compared with conventional TKRs [15, 17, 22, 39], they have not been shown to increase the risk of deep infections [20].

Cost

An economic analysis using the Markov model to compare the cost-effectiveness of TKR using computer-assisted surgery (CAS) with that of TKR using a conventional method used the rate of post-operative malalignment reduction as surrogate end point to estimate the long-term effectiveness of computer-assisted devices [8]. The analysis showed that computer-assisted surgery has a moderate ten-year cost saving of 583 and a small gain of 0.0148 quality-adjusted life years (QALYs) over ten years [8]. Given the yet unproven correlation between the slight improvement in alignment with CAS and clinical benefits a definitive assessment of the cost-effectiveness of this technology will require long-term evidence from randomised trials.

Summary

Total knee replacement is a very successful operation with a very high level of patient satisfaction and functional outcome. The current review has shown that navigational knee arthroplasty confers no significant benefits on the basis of radiographic end points or short-term clinical outcomes. It remains to be seen whether the marginal improvement in alignment with CAS would translate to better long-term clinical outcomes, and therefore a definitive assessment of the cost-effectiveness of this technology cannot be made at present. The benefit of computer-assisted devices probably lies in reducing the outliers defined by the post-operative malalignment greater than ±3° in tibial or femoral components or mechanical leg axis.

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