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Patient-Level Hospital Costs and Length of Stay After Conventional Versus Minimally Invasive Total Hip Replacement: A Propensity-Matched Analysis

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A B S T R A C T

Objectives: A current trend in total hip replacement (THR) is the use of minimally invasive surgery. Little is known, however, about the impact of minimally invasive THR on resource use and length of stay. This study analyzed the effect of minimally invasive surgery on hospital costs and length of stay in German hospitals compared with conventional treatment in THR. **Methods:** We used patient-level administrative hospital data from three German hospitals participating in the national cost data study. We conducted a propensity score matching to account for baseline differences between minimally invasively and conventionally treated patients. Subsequently, we estimated the treatment effect on costs and length of stay by conducting group comparisons, via paired *t* tests and Wilcoxon signed-rank tests, and regression analyses. **Results:** The three hospitals provided data from 2886 THR patients. The propensity score matching led to 812 matched pairs. Length of stay was significantly higher for conventionally treated patients (11.49 days vs. 10.90 days; $P < 0.05$), but total costs did not differ significantly (€6018 vs. €5986; $P = 0.67$). We found a difference in the allocation of costs, with significantly higher implant costs for minimally invasively treated patients (€1514 vs. €1375; $P < 0.001$) in contrast to significantly higher staff and overhead costs for conventionally treated patients. **Conclusions:** Minimally invasive surgery was compared with conventional THR and was found to be associated with a reduced length of stay. Total hospital costs, however, did not differ between the two treatment groups, because of higher implant costs for minimally invasively treated patients.

Keywords: economics, hip arthroplasty, hospital, minimally invasive.

Introduction

Total hip replacement (THR) has been described as "the operation of the century" [1]. It is a high-volume surgical procedure [2] that is considered to be successful for the treatment of diseases such as coxarthrosis [3]. With approximately 200,000 procedures each year, hip replacement is one of the most frequent kinds of surgery in German hospitals [4]. Because of demographic change and the increasing use of this procedure in older age groups, the demand for hip replacement is expected to increase further [5–8]. In recent years, there is a trend of using minimally invasive (MI) surgery approaches in THR [1]. MI surgery approaches were developed on the basis of conventional approaches and are supposed to reduce pain, postoperative blood loss, rehabilitation time, and length of hospital stay [9]. Similar to conventional procedures in THR, a variety of different MI approaches exist [10] but a coherent definition of MI THR is lacking [11]. In some articles, an MI THR is defined by the length of incision (<10 cm) [12–15], whereas in other articles, it is defined by the minimization of tissue and muscle dissection [16]. Although a number of studies have been published that compare MI THR with conventional THR, evidence about its relative merits is still limited [10,17–19]. In particular, the direct costs of an MI procedure in THR for hospitals have hardly been studied [20] despite the fact that, given the high number of THR procedures, even slight changes in direct costs can be expected to be important for the respective hospitals.

In this study, we assessed the effect of MI THR surgery on direct hospital costs and length of stay (LOS) in German hospitals compared with the effect of convention surgery for THR.

Material and Methods

We used patient-level administrative hospital data from German hospitals participating in the national cost data study conducted by the Institute for the Hospital Remuneration System. The data include sociodemographic, medical, and treatment information, as well as cost data. Hospitals participating in the national cost data study use a standardized cost accounting approach, reporting direct hospital costs in 99 cost categories. Treatment information includes type of treatment, provided by the German procedure codes (Operationen- und Prozedurenschlüssel [OPS]), and date of treatment. Medical information is given by *International Statistical Classification of Diseases, 10th Revision, German Modification* (ICD-10-GM) (Version 2008), including principal and secondary diagnoses recorded during hospital admission, along with conditions acquired or developed during the hospital stay. A distinction be-

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tween diagnosis at admission and conditions acquired at the hospital is only partially possible as the administrative data in Germany do not formally make this differentiation.

From approximately 250 hospitals, 31 that participated in the national cost data study provided patient-level data from the year 2008. We identified patients with a recorded primary THR by using the first five digits of the OPS codes 5-820.0x and 5-820.2x. As no specific OPS code exists for MI THR, we classified patients as MI treated if the OPS code 5-986 "minimally invasive technique" was recorded. Patients who had also undergone a revision hip arthroplasty, identified by OPS code 5-821.xx, were excluded from the analysis. Hospitals with either no conventional THR or no MI THR were excluded, as we aimed to compare MI and conventional cases from the same hospitals.

We contacted the remaining hospitals and asked 1) whether they coded MI THR consistently via the OPS code 5-986 and 2) which treatment patterns were a prerequisite for coding a patient as MI THR. After consultation with the relevant professional medical association, we included only those hospitals in the sample that consistently coded MI THR via the OPS code 5-986 given a surgical approach that minimizes tissue and muscle dissection. The hospitals kept in the sample were recontacted and were asked to provide data from 2009.

For our outcome variable "total cost", we summed up all reported costs. To allow further analysis, we grouped the 99 cost categories into the following 7 categories: staff costs—medical service; staff costs—nursing service; staff costs—medical-technical service; pharmaceutical costs; implant costs; costs for further medical devices; and overhead costs.

We calculated the LOS as the difference between the date of admission and the date of discharge. We also divided the LOS into further categories: preoperative LOS (pre-LOS), the difference between the date of admission and the date of surgery, and postoperative LOS (post-LOS), the difference between the date of surgery and the date of discharge.

Using observational studies for the analysis of treatment effect suffers from one drawback in comparison with randomized controlled trials: Individuals who receive treatment (MI surgery) are likely to differ in various baseline characteristics from those who do not (conventional surgery). These differences may affect the outcome, leading to biased estimates of the treatment effect [21]. Nevertheless, using administrative data has some advantages: it allows for treatment to be examined as it occurs in routine clinical care [22] and includes relatively large sample sizes [23]. Since individuals in routine clinical care are not randomly assigned for treatment, methods adjusting for the missing randomization have to be applied [24]. To address the treatment-selection bias, we applied propensity score matching [25]. In the propensity score method, all covariates that might predict treatment and influence the outcome are reduced into a single score, which represents the probability of treatment assignment conditional on observed background covariates [26]. Assuming that no other confounders exist, matching on propensity scores mimics a randomized treatment assignment, with matched treated and untreated individuals having the same probability of being treated.

We estimated the probability of selection for MI surgery (the propensity scores) by using multivariate logistic regression analysis. In the model we included all potential confounders, that is, factors that had been reported to be associated with both treatment selection and outcome (costs and LOS). We identified confounders on the basis of a literature search, leading to a total of four confounding factors for our propensity score model: age [27–31], sex [27,28,30,31], obesity [32–35], and the diagnosis indicating the THR (e.g., coxarthrosis or osteonecrosis) [27]. Since according to previous studies various factors are associated with LOS and hospital costs and an extended LOS has been associated with an increase in resource use [29,30,36,37], we used the same propensity scores and consequently the same matched sample for both variables of interest (total costs and LOS).

In addition, we included dummy variables indicating the hospital of treatment, because this approach has been reported suitable to account for a hierarchical data structure (in our study, patients treated in hospitals) [38]. To avoid confounding by different years of the data, we conducted a subgroup matching. We first calculated the propensity scores and conducted the matching for each year separately. Subsequently, we merged the 2008 and 2009 data.

The matching was conducted by using a one-to-one caliper matching with replacement. On the basis of previously published studies, we chose a caliper width of 0.2 of the SD of the logit of the propensity score [39] and assessed the matching quality by using standardized differences [40]. We rated standardized differences of up to 10% between the covariates as adequately balanced [41]. After the matching, we excluded all nonmatched cases from the sample and conducted all further statistical analysis by using the matched sample.

The effect of the treatment strategy was analyzed in two steps. In a first step, differences between the two treatment groups in our outcome variables (costs and LOS), as well as in the respective subgroups, were assessed by using paired *t* test and, as a nonparametric alternative, Wilcoxon signed-rank test.

In a second step, we applied generalized linear models (GLMs) to estimate the effect of an MI treatment on total costs and LOS. We used generalized estimating equations to account for the matched data structure. In the GLMs, we controlled for additional factors that had been associated with hospital costs and LOS: further treatment strategies, such as acetabular roof construction; type of implant (cementless, cemented, or hybrid) [29,42,43]; type of admission (emergency or elective) [44]; and comorbidities assessed through the Charlson index [37]. We included these factors only in the GLMs but not in the propensity score matching either because they were not related to treatment selection or because they could not be determined before treatment. In the GLMs with LOS as the dependent variable, we specified a model with a Poisson distribution and a log-link. For the dependent variable total cost, we specified a model with a normal distribution and the natural log of the costs as the dependent variable.

In the propensity score model and the GLMs, we included all factors using dummy variables, except for the continuous variable age. The value of the dummies was set as 1 if the treatment or the diagnosis had been reported and as 0 if it had not been reported. We retrieved all necessary information from the sociodemographic and medical information included in the administrative electronic patient files. Obese patients (body mass index > 30 kg/m^2) were identified by using the ICD-10 code E66. To include the diagnosis leading to the THR, we grouped the cases according to their main diagnosis. If a case had a primary diagnosis not related to THR, we screened all secondary diagnoses and grouped according to those. Finally, we grouped the diagnosis into the five dummy variables: coxarthrosis, fracture, arthritis, osteonecrosis, and others.

In addition, we applied the enhanced ICD-10–based version of the Charlson index [45,46] to account for comorbidities. Following this approach, we first calculated a weighted global Charlson index score by identifying the relevant ICD-10 codes recorded as secondary diagnoses and by overweighting the 6 most severe among the 17 dimensions of comorbidity proposed by Charlson: the "Hemiplegia/Paraplegia," "Renal disease," and "Cancer (any malignancy)" comorbidities are weighted by a coefficient 2, cases of "Moderate or severe liver diseases" by a coefficient 3, and "Metastatic solid tumor" and the "AIDS/HIV" cases by a coefficient 6 (see Charlson et al. [45] for details). We then used the Charlson index score to group patients into two dummy variables: Charlson1 (patients suffering from one single nonsevere comorbidity; Charlson score = 1) and Charlson2 (patients suffering from at least one severe or two nonsevere comorbidities; Charlson score > 1).