NIH Public Access
Author Manuscript
Best Pract Res Clin Rheumatol. Author manuscript; available in PMC 2014 January 03.

Published in final edited form as:
Best Pract Res Clin Rheumatol. 2012 October ; 26(5): . doi:10.1016/j.berh.2012.07.013.

The cost-effectiveness of total joint arthroplasty: a systematic review of published literature

Meghan E. Daigle, **Alexander M. Weinstein**, **Jeffrey N. Katz**, and **Elena Losina**
Orthopaedic and Arthritis Center for Outcomes Research, Department of Orthopaedic Surgery (EL, MED, AMW, JNK), Brigham and Women's Hospital, Boston, MA; Harvard Medical School, Boston, MA (EL, JNK); Boston University School of Public Health, Boston, MA (EL)

Abstract

Objective—To summarize the state of the literature evaluating the cost-effectiveness of elective total hip and knee arthroplasty (THA and TKA).

Methods—We conducted a systematic review of published cost-effectiveness analyses of THA and TKA. In order to limit our search to high-quality published papers, we selected those papers included in the Cost-Effectiveness Analysis Registry (created by the Center for the Evaluation of Value and Risk in Health at Tufts University) and augmented the search with papers listed in PubMed. The data abstracted included incremental cost-effectiveness ratios, perspective of the analysis, timeframe, discounting rates, and utility assessment. All cost-effectiveness ratios were converted to 2011 USD.

Results—Seven studies presenting cost-effectiveness ratios for TKA and six studies for THA were included in our review. All economic evaluations of TKA were published between 2006 and 2012. In contrast, THA studies were published between1996 and 2008. Out of the 13 studies evaluated in this review, four were from the societal perspective and eight were from the payer perspective. Seven studies spanned the lifetime horizon. Of the selected studies, six used probabilistic sensitivity analysis to address uncertainty in data parameters. Both procedures have been shown to be highly cost-effective from the societal perspective over the entire life-span.

Conclusion—THA and TKA have been found to be highly cost-effective in a number of high-quality studies. Further analyses are needed on the cost-effectiveness of alternative surgical options, particularly osteotomy. Future economic evaluations should address the expanding indications of THA and TKA to younger, more physically active individuals.

Keywords

cost-effectiveness; total knee arthroplasty; total hip arthroplasty

INTRODUCTION

Utilization of total hip arthroplasty (THA) and total knee arthroplasty (TKA), the two most common joint replacement surgeries, has increased dramatically over the last decade, with

© 2012 Elsevier Ltd. All rights reserved.

Correspondence: Elena Losina, PhD, Department of Orthopaedic Surgery, Orthopaedic and Arthritis Center for Outcomes Research, Brigham and Women's Hospital, 75 Francis St. BC-4, Boston, MA 02115, Elosina@partners.org, (617) 732 - 5338.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

NIH-PA Author Manuscript
NIH-PA Author Manuscript
NIH-PA Author Manuscript

NIH-PA Author Manuscript

NIH-PA Author Manuscript

NIH-PA Author Manuscript

THA and TKA utilization nearly doubling.[1] Nearly 300,000 THAs and over 600,000 TKAs were performed in the US in 2009. The surgeries have proven highly effective,[2,3] but are also very costly.[4,5] Cost-effectiveness analysis, one of the most common and well-established methods in economic evaluation,[6–8] assesses the value of an intervention strategy relative to an alternative strategy on the basis of cost and both quality and quantity of life.

In light of the increasing number of joint replacement surgeries, it is important to understand the published evidence establishing the economic value of total joint arthroplasty (TJA). There have been several previous reviews of the cost-effectiveness of TJA in the past ten years. Two studies by Brauer and colleagues reviewed cost-effectiveness analyses in orthopedic surgery generally, with a focus on the quality of the existing studies.[9,10] A 2004 literature review and analysis by Bozic and colleagues examined economic evaluation in THA, with a similar focus on methodological quality.[11] These reviews each found that the dearth of studies and inadequate methodological quality of existing studies limited the role of economic evaluation of TJA in guiding policy. Two other literature reviews have highlighted economic evaluation of specific approaches to TJA, such as minimal incision THA and computer-assisted navigation in TKA.[12,13] Furthermore, aside from the reviews more narrowly focused on specific surgical approaches, these recent reviews did not include studies published later than 2003. No literature review has been published summarizing studies examining the cost-effectiveness of TKA in general.

We conducted a systematic review of cost-effectiveness analyses of THA and TKA in the medical literature. We sought to create a resource for decision-makers by listing published cost-effectiveness ratios for these common joint replacement surgeries. Our review included papers published between January 1, 1980 and February 1, 2012. We used the recommendations of the Panel on Cost-Effectiveness in Health and Medicine[6–8] as a guide for selecting high-quality papers for our review. We sought to establish whether there is consistent evidence of the economic value of TJA, and to identify gaps in the literature as well as analyses which may need to be updated.

METHODS

Overview

To ensure that we considered only high-quality studies we first searched the Cost-Effectiveness Analysis (CEA) Registry, a well-established high-quality repository of cost-effectiveness analyses compiled by the Center for the Evaluation of Value and Risk in Health at Tufts University, for economic evaluations of THA and TKA.[14] The CEA Registry has strict inclusion criteria. Because papers are thoroughly reviewed, there is a delay between the time a paper is published and the time it may appear in the Registry. Therefore, we supplemented the CEA Registry search with a search of studies from PubMed.[15] We abstracted and characterized cost-effectiveness data from the studies passing our inclusion criteria presented below.

The CEA Registry

The CEA Registry is an ongoing project that summarizes published cost-effectiveness papers on a wide range of medical conditions.[14] The Registry contains more than 1900 entries. The Registry summarizes and reviews published, original, English-language cost-utility analysis articles. The articles undergo a rigorous screening and review process before being included in the Registry. Papers must contain the terms “QALYs”, “quality”, and “cost-utility analysis”; only papers using quality-adjusted life years as part of the cost-

NIH-PA Author Manuscript

NIH-PA Author Manuscript

NIH-PA Author Manuscript

effectiveness analysis are included in the registry. Reviews and methodological articles are excluded from the CEA Registry.

Initial Screening for Economic Evaluations Pertinent to THA and TKA

Our initial screening process consisted of three steps: (1) title screening, (2) abstract screening, and (3) paper screening. In the title screening, we searched for papers in the CEA Registry with "[joint]" and either "arthoplast*" or "replacement" (where [joint] is either "hip" or "knee") in the title. We then reviewed titles and abstracts of papers passing the title screening, and excluded papers beyond the scope of this review. Specifically, we excluded papers evaluating the cost-effectiveness of: pre- or postoperative treatment strategies, adverse event prophylaxis (mainly infection and deep vein thrombosis), or non-elective TJA (for example, THA as treatment for hip fracture). In the paper screening step, we reviewed the remaining papers and excluded those which did not report true incremental cost-effectiveness ratios (ICERs), defined as the change in cost over the change in quality-adjusted life expectancy between two or more alternative treatment strategies.

Addition of Papers from PubMed

Our PubMed search terms required that the title or abstract included the joint (hip or knee) and that the title included either "arthroplast*" or "replacement". Additionally, one of the following three sets of criteria had to be met: (1) the paper had the major Medical Subject Headings (MeSH) "Cost-Benefit Analysis," as well as either "Arthroplasty, Replacement, [joint]/economics" or "[joint] Prosthesis/economics"; (2) the paper had the general MeSH terms "Arthroplasty, Replacement, [joint]/economics," "Cost-Benefit Analysis," and "Quality-Adjusted Life Years"; or (3) the title contained either "cost effective" or "cost utility." Our search terms also excluded papers with any of the following terms in the title: "prevent*," "screen*," "preoperative," "prophylaxis," "blood*," "treat*," "rehab*," "thromboprophylaxis," "rivaroxaban," "transfusion*," "autotransfusion*," "postoperative," "warfarin," "infect*," "hormone*," or "discharge". These exclusions limited the number of papers returned which primarily evaluated methods of adverse event prevention, non-elective procedures, and pre- or post-operative care. We limited our search results to papers published between January 1, 1980 and February 1, 2012 with available abstracts. We then reviewed the remaining papers, eliminating those papers which were not in English, papers which were already evaluated as part of the CEA Registry screening, papers meeting our exclusion criteria, or papers not reporting true cost-effectiveness ratios. Note that our screening process for the CEA Registry consisted of three steps: (1) title screening, (2) abstract screening, and (3) paper screening. Due to the nature of the PubMed search engine, we conducted the PubMed screening in two steps: (1) the initial search query (title/abstract screening); and (2) manual review of the returned papers (abstract/paper screening). These differences are reflected in Figure 1.

Data Abstraction

CEA Registry and PubMed papers passing the screening process moved on to data abstraction. As part of this process, we recorded the following data for each study: comparison made (TJA vs. no surgery, surgical approach, or alternative surgery); study perspective, defined as societal or payer (where the societal perspective incorporates costs due to productivity loss in addition to direct costs of treatment, and the payer perspective includes only direct costs); time horizon; utility assessment, defined as either direct or indirect (based on the survey technique for determining health-state preferences); monetary units; ICERs; and sensitivity analyses conducted (probabilistic if parameters were varied over a probability distribution, and deterministic if specific variations in parameters were used). Please refer to the Glossary for further explanation of cost-effectiveness terminology. All ICERs were converted to 2011 USD.

NIH-PA Author Manuscript

NIH-PA Author Manuscript

NIH-PA Author Manuscript

Quality Scoring

We graded the quality of papers on a scale of 1 to 7. Papers started with a score of 7 and lost points if certain criteria were not met. One point was subtracted from the paper's overall quality score for each data abstraction category (that is, comparison, perspective, preference measurement, or monetary units) that was not clearly defined. Additionally, one half of a quality point was subtracted for analyses conducted from the payer, rather than the societal, perspective. One whole quality point was lost for papers conducted over less than or equal to 20 years (approximately the survival of a hip or knee prosthesis). One half of a quality point was subtracted for papers not conducted over the lifetime horizon, but greater than 20 years. Papers not conducting clearly defined deterministic or probabilistic sensitivity analyses lost one quality point.

RESULTS

Papers Screening and Inclusion

Title screening in the CEA Registry yielded 14 TKA papers and 19 THA papers which included the joint ("hip" or "knee") as well as either "replacement" or "arthroplast" in the title. One paper comparing the cost-effectiveness of metal-on-metal hip resurfacing to THA was excluded because it did not include the "replacement" or "arthroplast" in the title.[16] One paper evaluating the cost-effectiveness of both THA and TKA was excluded at this step because it did not contain the words "hip" or "knee" in the title; this paper would not have passed the paper screening step because it did not report true ICERs.[17] Five TKA papers and 11 THA papers were excluded in the abstract screening because they primarily evaluated non-elective surgery, adverse event prevention, or pre- or postoperative care.[18–29] Three TKA and five THA papers were excluded in the paper screening step because they did not report true ICERs.[30–36] Of the remaining papers, six TKA and three THA papers reported true ICERs and moved on to the data abstraction step.[37–45]

Our initial PubMed search returned 40 TKA papers and 50 THA papers. After eliminating papers which were already reviewed as part of the CEA Registry search and papers which did not report true ICERs, we found one additional TKA paper and three additional THA papers to review.[46–49] A summary of the number of CEA Registry and PubMed papers passing each screening step is presented in Figure 1.

Out of the 13 papers included in the detailed review, three papers compared surgery to no surgery, six focused on surgical approach, one compared hip resurfacing to THA, and three compared unicompartmental knee arthroplasty (UKA) to TKA. Four economic evaluations were conducted from the societal perspective, as recommended by the Panel on Cost-effectiveness in Medicine.[6–8] Seven analyses were conducted over the lifetime horizon, one was conducted over a horizon greater than 20 years. The remaining five studies were conducted over fewer than 20 years. All studies clearly defined and presented sensitivity analyses, with six studies presenting probabilistic sensitivity analyses to address uncertainty in data inputs. Overall characteristics of the papers passing the paper screening are presented in Table 1.

The average quality score among both THA and TKA papers was estimated at 5.8. Quality scores ranged from 4 to 7 on a 7 point scale, with 7 representing the best quality.

Volume of Economic Evaluation of TJA over Time

The earliest paper estimating the cost-effectiveness of TJA was published in 1996.[37] It presented a detailed cost-effectiveness analysis of THA from the societal perspective. The first published paper establishing the cost-effectiveness of TKA from the societal

NIH-PA Author Manuscript

NIH-PA Author Manuscript

NIH-PA Author Manuscript

perspective was published in 2006.[42] The increasing volume of papers on TJA cost-effectiveness over time is presented in Figure 2.

Characteristics of the studies which passed the entire screening process are presented in Table 2. No analysis of the cost-effectiveness of THA versus no surgery has been completed since a high quality study in 1996, which found THA to be highly cost-effective.[37] The most recent THA analysis evaluated the cost-effectiveness of cement versus no cement.[48] Additional analyses have compared various prosthesis types and materials, as well as the cost-effectiveness of hip resurfacing.[38,45,47,49] Several high-quality TKA papers have compared the cost-effectiveness of UKA versus TKA.[41–43] The cost-effectiveness of computer assisted navigation has also been evaluated.[39,40]

Economic Evaluation Pertinent to TJA

The cost-effectiveness of THA compared to no surgery has been estimated at $10,402 per quality-adjusted life year (QALY) gained (2011 USD); if the World Health Organizations' suggested cost-effectiveness threshold of less than 3 times the gross domestic product (GDP), or $144,000 based on 2011 data for the US, is used, THA can be considered highly cost-effective.[37,50,51] TKA has been similarly shown to be a very cost-effective procedure. Estimated cost-effectiveness ratios range from $12,000/QALY over a 5-year time horizon from the payer perspective to $20,000/QALY from the societal perspective and over the lifetime horizon.[44,46] Details for these studies are presented in Table 2.

There have been several economic evaluations of the value of improved implants for THA.[38,47,49] In these evaluations, implants with higher costs, but with lower failure rates were evaluated relative to standard, lower costing implants with higher revision rates. In two studies, improved implants were shown to be cost saving in cohorts aged 60 or younger.[38,49] In a third study, these implants were found to have an ICER of $17,671 (2011 USD) among 68 year-olds.[47] Metal-on-metal hip resurfacing was evaluated over a 20-year time horizon in one paper, but was found to be dominated by THA.[45] The use of cement was evaluated in one THA manuscript, but neither cement nor cementless implants were found to offer uniformly better value (Table 2).[48]

Computer-assisted navigation has been shown to be cost-saving over a 10-year time horizon and to have an ICER of $54,000/QALY over a 15-year time horizon from the payer perspective.[39,40] UKA has been established as either cost-saving or cost-effective (with ICERs below 3 times the GDP) in three studies (Table 2).[41–43]

DISCUSSION

This paper summarizes published economic evaluations related to TJA. Over the course of the last 15 years, there have been 13 published economic evaluations related to TJA, with an average quality score of 5.8. Six of these publications were economic evaluations related to THA.[37,38,45,47–49] Only one study, published more than a decade ago, reported a very favorable ICER for THA compared to no surgery; this study did not consider individuals younger than 60 years of age.[37] No additional studies have been published to address this question. Other economic evaluations relevant to THA focused on the value of improved implants in THA.[38,47,49] These studies suggested that under a set of assumptions these innovations offer good value for money spent. There have been seven published economic evaluations of TKA, which have suggested that TKA is a very cost-effective procedure.[39–44,46] More recent studies have reported a wide range of ICERs for UKA relative to TKA in persons with unicompartmental disease.[41–43] This suggests that the value of UKA depends greatly on the population under consideration, study perspective, and time

NIH-PA Author Manuscript

NIH-PA Author Manuscript

NIH-PA Author Manuscript

horizon. The value of computer navigation in TKA delivery also depends greatly on the same set of underlying assumptions.[39,40]

Our systematic review builds upon two previous reviews of cost-effectiveness analyses in orthopedic surgery.[9,10] While two reviews by Brauer et al. focused on the methodological quality of existing studies, our review has focused on summarizing what evidence the existing literature has established for the cost-effectiveness of TKA and THA. Additionally, while the reviews by Brauer et al. included papers up through 2001, the majority of studies included in this review, particularly for TKA, were published after 2001.

While this systematic review identified a substantial number of papers with the words "cost-effectiveness" in the titles or abstracts, we found relatively few detailed, comprehensive economic evaluations of TJA, and few met the high standards for cost-effectiveness analyses set forth in the Recommendations of the Panel on Cost-Effectiveness in Health and Medicine.[6–8] Specifically, we found very few analyses which: were conducted from the societal perspective, took place over the lifetime horizon, or conducted extensive sensitivity analyses.

Results of this systematic review should be viewed in light of certain limitations. Despite the clarity of the recommendations of the Panel on Cost-Effectiveness in Health and Medicine, there was a high level of heterogeneity in reported results among the reviewed economic evaluations. This made the standardization of abstracted data challenging. Without a standardized time horizon or study perspective, comparing and summarizing the results of different studies is difficult.

TJA utilization has increased dramatically in the past decade, which raises questions regarding the applicability of economic evaluations conducted over ten years ago. There is a need to update analyses of THA taking into consideration the widening indications of surgery. Little work has been done in examining the cost-effectiveness of offering THA or TKA to patients at a higher level of function in order to limit loss of functional capacity. Economic evaluations are needed for osteotomy. Based on the current state of evidence, conflicting data exist regarding the cost-effectiveness of UKA and use of computer navigation.

This review has indicated the need for detailed data on various patient outcomes after THA and TKA, as well as the need for computer-simulation modeling analyses to project these data over the life-span and predict the long-term, societal impact of TJA. Furthermore, establishing the cost-effectiveness of TJA is a necessary first step toward understanding how to pay for these remarkably effective but nonetheless costly procedures.

Acknowledgments

Supported by NIH/NIAMS R01 AR053112, K24 AR057827.

Glossary

Deterministic Sensitivity Analysis	Analyses which consider that the values of certain parameters may vary. The parameter value is changed and the effect on cost-effectiveness is examined.
Incremental Cost-	The ratio of the change in costs divided by the change in quality-adjusted life expectancy between two alternative treatment strategies.

NIH-PA Author Manuscript

NIH-PA Author Manuscript

NIH-PA Author Manuscript

effectiveness Ratios	
Perspective	Cost-effectiveness analyses may be conducted from different perspectives. In this review, we consider studies conducted from the following perspectives: **1.** Societal **2.** Payer Studies conducted from the societal perspective include both direct costs of treatment (hospital stay, medication costs) as well as indirect costs of treatment (such as productivity losses) Studies conducted from the payer perspective include only direct costs.
Probabilistic Sensitivity Analysis	Probabilistic sensitivity analyses consider variations in parameters over a distribution. The effect of variations across the given distribution on cost-effectiveness is examined.
Quality-adjusted Life Year	A year of life that has been decremented based on the individual's utility in that year.
Utility	Utility is a measure of quality of life and is on a scale between 0 (worst possible health state) and 1 (perfect health). The value of the utility reflects preference for certain health states over others.
Utility Assessment	Utility may be measured in two ways: **1.** Directly **2.** Indirectly Direct measurement of utility can be done using questionnaires of standard gamble or time-trade off. Indirect measurement of utility can be done using surveys such as the SF-36 (Short- Form) or Euro QoL.

References

1. Healthcare Cost and Utilization Project (HCUP). [Accessed July 8, 2012.] Nationwide Inpatient Sample (NIS). <http://hcupnet.ahrq.gov/ >
2. Paxton EW, Namba RS, Maletis GB, Khatod M, Yue EJ, Davies M, Low RB Jr, Wyatt RW, Inacio MC, Funahashi TT. A prospective study of 80,000 total joint and 5000 anterior cruciate ligament reconstruction procedures in a community-based registry in the United States. J Bone Joint Surg Am. 2010; 92 (Suppl 2):117–132. [PubMed: 21123596]
3. Katz JN, Mahomed NN, Baron JA, Barrett JA, Fossel AH, Creel AH, Wright J, Wright EA, Losina E. Association of hospital and surgeon procedure volume with patient-centered outcomes of total knee replacement in a population-based cohort of patients age 65 years and older. Arthritis Rheum. 2007; 56(2):568–574. [PubMed: 17265491]
4. Medicare Fee Schedules. Centers for Medicare & Medicaid Services; 2010. <http://www.cms.gov/home/medicare.asp > [Accessed July 8, 2012.]
5. Medicare Hospital Inpatient Prospective Payment System. Centers for Medicare & Medicaid Services; 2010. <http://www.cms.gov/MedicareFeeforSvcPartsAB/03_MEDPAR.asp > [Accessed July 8, 2012.]
6. Siegel JE, Weinstein MC, Russell LB, Gold MR. Recommendations for Reporting Cost-effectiveness Analyses. JAMA. 1996; 276(16):1339–1341. [PubMed: 8861994]

NIH-PA Author Manuscript

NIH-PA Author Manuscript

NIH-PA Author Manuscript

7. Weinstein MC, Siegel JE, Gold MR, Kamlet MS, Russell LB. Recommendations of the Panel on Cost-effectiveness in Health and Medicine. JAMA. 1996; 276(15):1253–1258. [PubMed: 8849754]
8. Gold, MR.; Siegel, JE.; Russel, LB.; Weinstein, M., editors. Cost-effectiveness in health and medicine. New York: Oxford University Press; 1996.
9. Brauer CA, Neumann PJ, Rosen AB. Trends in cost effectiveness analyses in orthopaedic surgery. Clin Orthop Relat Res. 2007; 457:42–48. [PubMed: 17242614]
10. Brauer CA, Rosen AB, Olchanski NV, Neumann PJ. Cost-utility analyses in orthopaedic surgery. J Bone Joint Surg Am. 2005; 87(6):1253–1259. [PubMed: 15930533]
11. Bozic KJ, Saleh KJ, Rosenberg AG, Rubash HE. Economic evaluation in total hip arthroplasty: analysis and review of the literature. The Journal of Arthroplasty. 2004; 19(2):180–189. [PubMed: 14973861]
12. de Verteuil R, Imamura M, Zhu S, Glazener C, Fraser C, Munro N, Hutchison J, Grant A, Coyle D, Coyle K, Vale L. A systematic review of the clinical effectiveness and cost-effectiveness and economic modelling of minimal incision total hip replacement approaches in the management of arthritic disease of the hip. Health Technol Assess. 2008; 12(26):iii–iv. ix–223. [PubMed: 18513467]
13. Desai AS, Dramis A, Kendoff D, Board TN. Critical review of the current practice for computer-assisted navigation in total knee replacement surgery: cost-effectiveness and clinical outcome. Curr Rev Musculoskelet Med. 2011; 4(1):11–15. [PubMed: 21475560]
14. Center for the Evaluation of Value and Risk in Health. The Cost-Effectiveness Analysis Registry [Internet]. Boston: Institute for Clinical Research and Health Policy Studies, Tufts Medical Center; Avalilable from: www.cearegistry.org [Accessed on July 8, 2012]
15. PubMed [Internet]. Bethesda, (MD): National Library of Medicine (US); 2011.
16. Bozic K, Pui C, Ludeman M, Vail T, Silverstein M. Do the Potential Benefits of Metal-on-Metal Hip Resurfacing Justify the Increased Cost and Risk of Complications? Clinical Orthopaedics and Related Research. 2010; 468(9):2301–2312. [PubMed: 20232182]
17. Navarro Espigares JL, Hernandez Torres E. Cost-outcome analysis of joint replacement: evidence from a Spanish public hospital. Gac Sanit. 2008; 22(4):337–343. [PubMed: 18755084]
18. Kauppila AM, Kyllonen E, Ohtonen P, Hamalainen M, Mikkonen P, Laine V, Siira P, Maki-Heikkila P, Sintonen H, Leppilahti J, Arokoski JP. Multidisciplinary rehabilitation after primary total knee arthroplasty: a randomized controlled study of its effects on functional capacity and quality of life. Clin Rehabil. 2010; 24(5):398–411. [PubMed: 20354057]
19. Wolowacz SE, Roskell NS, Maciver F, Beard SM, Robinson PA, Plumb JM, Dolan G, Brenkel IJ. Economic evaluation of dabigatran etexilate for the prevention of venous thromboembolism after total knee and hip replacement surgery. Clin Ther. 2009; 31(1):194–212. [PubMed: 19243718]
20. Larsen K, Hansen TB, Thomsen PB, Christiansen T, Soballe K. Cost-effectiveness of accelerated perioperative care and rehabilitation after total hip and knee arthroplasty. J Bone Joint Surg Am. 2009; 91(4):761–772. [PubMed: 19339559]
21. Haentjens P, De Groote K, Annemans L. Prolonged enoxaparin therapy to prevent venous thromboembolism after primary hip or knee replacement. A cost-utility analysis. Arch Orthop Trauma Surg. 2004; 124(8):507–517. [PubMed: 15365714]
22. Birkmeyer JD, Goodnough LT, AuBuchon JP, Noordsij PG, Littenberg B. The cost-effectiveness of preoperative autologous blood donation for total hip and knee replacement. Transfusion. 1993; 33(7):544–551. [PubMed: 8333017]
23. Bolz KM, Crawford RW, Donnelly B, Whitehouse SL, Graves N. The cost-effectiveness of routine follow-up after primary total hip arthroplasty. J Arthroplasty. 2010; 25(2):191–196. [PubMed: 19195830]
24. Cummins JS, Tomek IM, Kantor SR, Furnes O, Engesaeter LB, Finlayson SR. Cost-effectiveness of antibiotic-impregnated bone cement used in primary total hip arthroplasty. J Bone Joint Surg Am. 2009; 91(3):634–641. [PubMed: 19255224]
25. Krummenauer F, Gunther KP, Witzlebf WC. The incremental cost effectiveness of in-patient versus out-patient rehabilitation after total hip arthroplasty - results of a pilot investigation. Eur J Med Res. 2008; 13(6):267–274. [PubMed: 18558552]

NIH-PA Author Manuscript NIH-PA Author Manuscript NIH-PA Author Manuscript

26. Skedgel C, Goeree R, Pleasance S, Thompson K, O'Brien B, Anderson D. The cost-effectiveness of extended-duration antithrombotic prophylaxis after total hip arthroplasty. J Bone Joint Surg Am. 2007; 89(4):819–828. [PubMed: 17403806]
27. Botteman MF, Caprini J, Stephens JM, Nadipelli V, Bell CF, Pashos CL, Cohen AT. Results of an economic model to assess the cost-effectiveness of enoxaparin, a low-molecular-weight heparin, versus warfarin for the prophylaxis of deep vein thrombosis and associated long-term complications in total hip replacement surgery in the United States. Clin Ther. 2002; 24(11):1960–1986. discussion 1938. [PubMed: 12501885]
28. Fisman DN, Reilly DT, Karchmer AW, Goldie SJ. Clinical effectiveness and cost-effectiveness of 2 management strategies for infected total hip arthroplasty in the elderly. Clin Infect Dis. 2001; 32(3):419–430. [PubMed: 11170950]
29. Geelhoed E, Harris A, Prince R. Cost-effectiveness analysis of hormone replacement therapy and lifestyle intervention for hip fracture. Aust J Public Health. 1994; 18(2):153–160. [PubMed: 7948331]
30. Rasanen P, Paavolainen P, Sintonen H, Koivisto A-M, Blom M, Ryynanen O-P, Roine RP. Effectiveness of hip or knee replacement surgery in terms of quality-adjusted life years and costs. Acta Orthopaedica. 2007; 78(1):108–115. [PubMed: 17453401]
31. O'Shea K, Bale E, Murray P. Cost analysis of primary total hip replacement. Ir Med J. 2002; 95(6): 177–180. [PubMed: 12171266]
32. Givon U, Ginsberg GM, Horoszowski H, Shemer J. Cost-Utility Analysis of Total Hip Arthroplasties: Technology Assessment of Surgical Procedures by Mailed Questionnaires. International Journal of Technology Assessment in Health Care. 1998; 14(04):735–742. [PubMed: 9885463]
33. Garellick, Gr; Malchau, H.; Herberts, P.; Hansson, E.; Axelsson, H.; Hansson, T. Life Expectancy and Cost Utility After Total Hip Replacement. Clinical Orthopaedics and Related Research. 1998; 346:141–151. [PubMed: 9577422]
34. Laupacis A, Bourne R, Rorabeck C, Feeny D, Wong C, Tugwell P, Leslie K, Bullas B. Costs of elective total hip arthroplasty during the first year: Cemented versus noncemented. The Journal of Arthroplasty. 1994; 9(5):481–487. [PubMed: 7807104]
35. Krummenauer F, Wolf C, Gunther KP, Kirschner S. Clinical Benefit and Cost Effectiveness of Total Knee Arthroplasty in the Older Patient. Eur J Med Res. 2009; 14(2):76–84. [PubMed: 19258217]
36. Lavernia CJ, Guzman JF, Gachupin-Garcia A. Cost effectiveness and quality of life in knee arthroplasty. Clin Orthop Relat Res. 1997; (345):134–139. [PubMed: 9418630]
37. Chang RW, Pellissier JM, Hazen GB. A Cost-effectiveness Analysis of Total Hip Arthroplasty for Osteoarthritis of the Hip. JAMA: The Journal of the American Medical Association. 1996; 275(11):858–865. [PubMed: 8596224]
38. Briggs A, Sculpher M, Dawson J, Fitzpatrick R, Murray D, Malchau H. The use of probabilistic decision models in technology assessment : the case of total hip replacement. Appl Health Econ Health Policy. 2004; 3(2):79–89. [PubMed: 15702945]
39. Dong H, Buxton M. Early assessment of the likely cost-effectiveness of a new technology: A Markov model with probabilistic sensitivity analysis of computer-assisted total knee replacement. Int J Technol Assess Health Care. 2006; 22(2):191–202. [PubMed: 16571195]
40. Novak EJ, Silverstein MD, Bozic KJ. The cost-effectiveness of computer-assisted navigation in total knee arthroplasty. J Bone Joint Surg Am. 2007; 89(11):2389–2397. [PubMed: 17974880]
41. Slover J, Espehaug B, Havelin LI, Engesaeter LB, Furnes O, Tomek I, Tosteson A. Cost-effectiveness of unicompartmental and total knee arthroplasty in elderly low-demand patients. A Markov decision analysis. J Bone Joint Surg Am. 2006; 88(11):2348–2355. [PubMed: 17079390]
42. Soohoo NF, Sharifi H, Kominski G, Lieberman JR. Cost-effectiveness analysis of unicompartmental knee arthroplasty as an alternative to total knee arthroplasty for unicompartmental osteoarthritis. J Bone Joint Surg Am. 2006; 88(9):1975–1982. [PubMed: 16951114]

NIH-PA Author Manuscript

NIH-PA Author Manuscript

NIH-PA Author Manuscript

43. Xie F, Lo N-N, Tarride J-E, O'Reilly D, Goeree R, Lee H-P. Total or partial knee replacement? Cost-utility analysis in patients with knee osteoarthritis based on a 2-year observational study. The European Journal of Health Economics. 2010; 11(1):27–34. [PubMed: 19430952]
44. Losina E, Walensky RP, Kessler CL, Emrani PS, Reichmann WM, Wright EA, Holt HL, Solomon DH, Yelin E, Paltiel AD, Katz JN. Cost-effectiveness of total knee arthroplasty in the United States: patient risk and hospital volume. Arch Intern Med. 2009; 169(12):1113–1121. discussion 1121–1112. [PubMed: 19546411]
45. McKenzie L, Vale L, Stearns S, McCormack K. Metal on metal hip resurfacing arthroplasty. An economic analysis. Eur J Health Econ. 2003; 4(2):122–129. [PubMed: 15609179]
46. Dakin H, Gray A, Fitzpatrick R, Maclennan G, Murray D. Rationing of total knee replacement: a cost-effectiveness analysis on a large trial data set. BMJ Open. 2012; 2(1):e000332.
47. Briggs A, Sculpher M, Britton A, Murray D, Fitzpatrick R. The costs and benefits of primary total hip replacement. How likely are new prostheses to be cost-effective? Int J Technol Assess Health Care. 1998; 14(4):743–761. [PubMed: 9885464]
48. Marinelli M, Soccetti A, Panfoli N, de Palma L. Cost-effectiveness of cemented versus cementless total hip arthroplasty. A Markov decision analysis based on implant cost. J Orthop Traumatol. 2008; 9(1):23–28. [PubMed: 19384477]
49. Bozic KJ, Morshed S, Silverstein MD, Rubash HE, Kahn JG. Use of cost-effectiveness analysis to evaluate new technologies in orthopaedics. The case of alternative bearing surfaces in total hip arthroplasty. J Bone Joint Surg Am. 2006; 88(4):706–714. [PubMed: 16595459]
50. Tan-Torres, Edejer T. Making choices in health : WHO guide to cost-effectiveness analysis. Tan-Torres Edejer, T., et al., editors. Geneva: World Health Organization; 2003.
51. The World Factbook. Washington, DC: 2012.

NIH-PA Author Manuscript

NIH-PA Author Manuscript

NIH-PA Author Manuscript

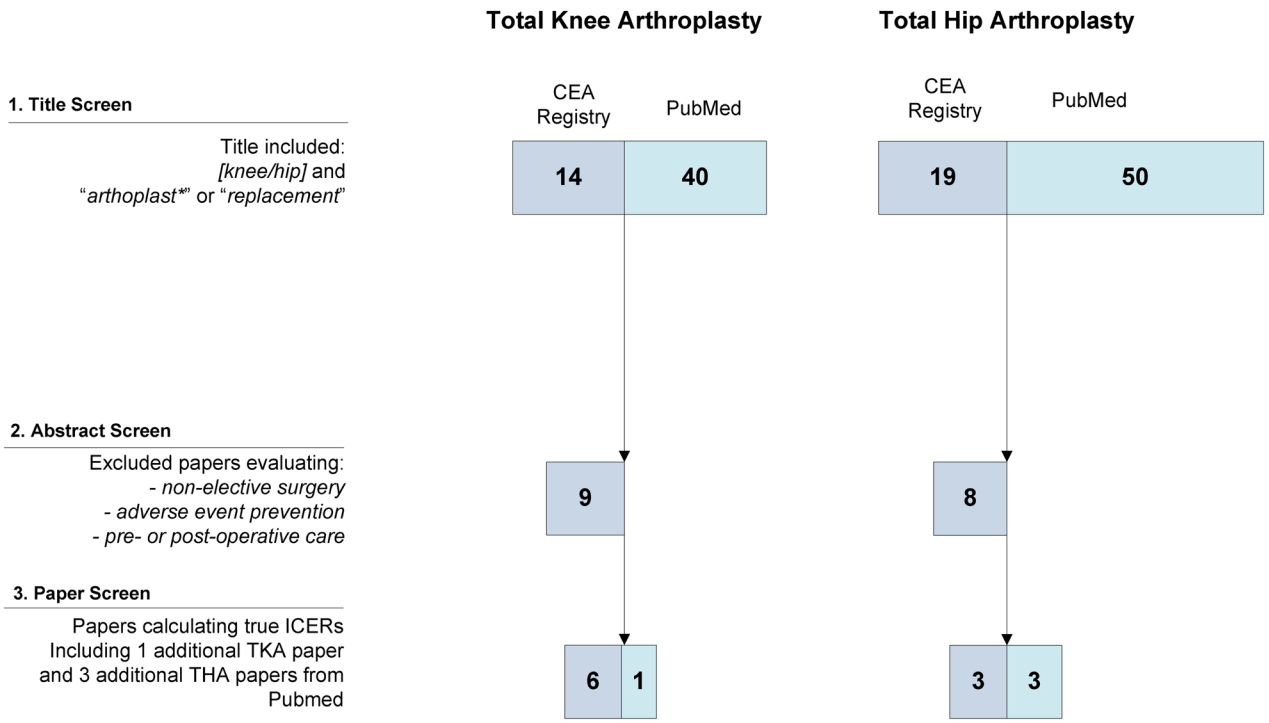

Figure 1. Number of Papers Passing Each Screening Stage

Note: Only CEA Registry Papers went through Step 2 (Abstract Screen). Pubmed papers that passed Step 1 (Title Screen) immediately passed to a combined paper and abstract screening step (Step 3).

NIH-PA Author Manuscript

NIH-PA Author Manuscript

NIH-PA Author Manuscript

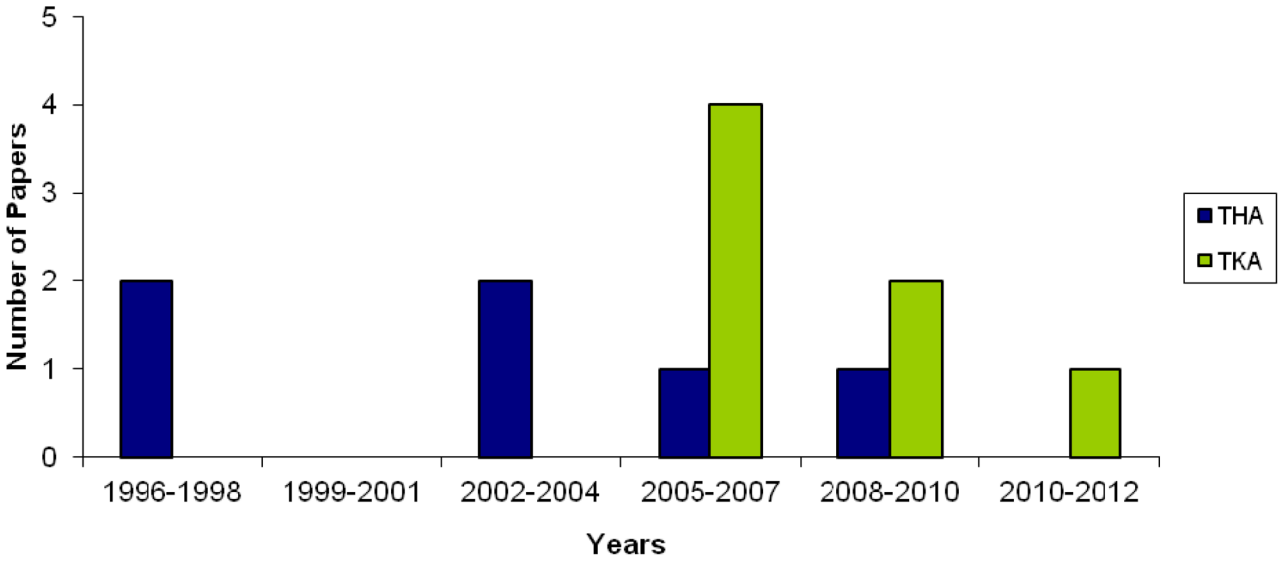

Figure 2.
Number of THA and TKA Papers over Time

NIH-PA Author Manuscript

NIH-PA Author Manuscript

NIH-PA Author Manuscript

Table 1

Characteristics of 13 Papers Passing Screening

Comparison Type*	**# Papers (13)**
Surgery vs. No Surgery	3
Surgical Approach	6
Surgery 1 vs. Surgery 2	4
Unclear (*−1 quality point*)	0
Perspective	
Societal	4
Payer (*−0.5 quality points*)	8
Not Stated (*−1 quality points*)	1
Time Horizon	
Lifetime	7
21+ years (*−0.5 quality points*)	1
0–20 years (*−1 quality points*)	5
Utility Assessment	
Direct	2
Indirect	6
Not Stated (*−1 quality point*)	5
Cost Units	
Clearly Defined	12
Not Clearly Defined (*−1 quality point*)	1
Sensitivity	
Probabilistic	6
Deterministic	12
None or Unclear (*−1 quality point*)	0

NIH-PA Author Manuscript NIH-PA Author Manuscript NIH-PA Author Manuscript

Table 2

Data Abstraction

Comparison	Paper		Perspective	ICER ($/QALY)	Time Horizon	Description	Quality Score
Total Hip Arthroplasty							
THA vs. No Surgery	Chang[37]	1996	Societal	**1** $10,402 **2** cost saving	Lifetime	**1** males, 85 yrs+ **2** females, 60 yrs	7
Improved Implant vs. Standard Implant	Briggs[47]	1998	Payer	$17,671	Lifetime	Mean age: 68 yrs. 4% reduction in revision rate, 300% increase in cost	6.5
	Briggs[38]	2004	Payer	cost saving	60 yrs	Age range: 40 – 60 yrs More costly Spectron implant with lower revision vs. less costly Charnley implant with higher revision	6
	Bozic[49]	2006	Not clear	cost saving	Lifetime	Age: 50 yrs; increase of $2000 for an implant with 19% reduction in 20–year failure rate	4
THA vs. Resurfacing	McKenzie[45]	2003	Payer	THA dominates	20 yrs	Age: < 65 years	5.5
Cementless vs. Cement	Marinelli[48]	2008	Payer	Neither option clearly better	Lifetime	Mean age: 70 yrs	5.5
Total Knee Arthroplasty							
CAS Vs. TKA	Dong[39]	2006	Payer	cost saving	10 yrs	Age range: 70 – 79 yrs	4.5
	Novak[40]	2007	Payer	$54,234	15 yrs	CAS costs $1500 more, improves precision by 14%	5
UKA vs. TKA	Slover[41]	2006	Payer	cost saving	Lifetime	Mean age: 78 yrs Revision rate <4% for UKA	6.5
	Soohoo[42]	2006	Societal	$458	Lifetime	Mean age: 65 yrs UKA: 12-yr survival, TKA 15-yr survival	6
TKA vs. UKA	Xie[43]	2010	Societal	$71,731	2 yrs	Mean age: 63 (UKA), 67 (TKA)	6
TKA vs. No Surgery	Losina[44]	2009	Societal	**1** $20,119 **2** $11,548	Lifetime	**1** mean age: 74 yrs **2** mean age: 69 yrs	7
	Dakin[46]	2012	Payer	$12,566	5 yrs	Mean age: 71 yrs	5.5

*All ICERs have been converted to in 2011 USD

NIH-PA Author Manuscript NIH-PA Author Manuscript NIH-PA Author Manuscript

Abbreviations: THA - total hip arthroplasty, TKA - total knee arthroplasty, CAS – computer assisted surgery, UKA - unicompartmental knee arthroplasty, ICER - incremental cost-effectiveness ratio, QALY – quality-adjusted life year