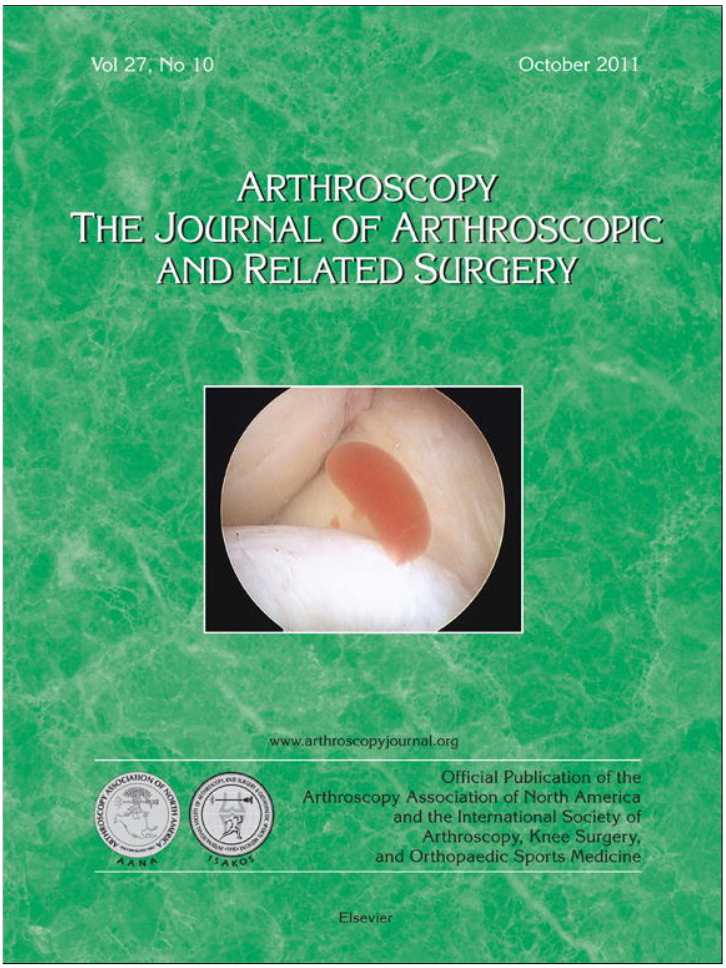

# Cost-Effectiveness Analysis of the Most Common Orthopaedic Surgery Procedures: Knee Arthroscopy and Knee Anterior Cruciate Ligament Reconstruction

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**Purpose:** The purpose of this study was to determine the cost-effectiveness of knee arthroscopy and anterior cruciate ligament (ACL) reconstruction. **Methods:** Retrospective analysis of prospectively collected data from a single-surgeon, institutional review board–approved outcomes registry included 2 cohorts: surgically treated knee arthroscopy and ACL reconstruction patients. Our outcome measure is cost-effectiveness (cost of a quality-adjusted life-year [QALY]). The QALY is calculated by multiplying difference in health-related quality of life, before and after treatment, by life expectancy. Health-related quality of life is measured by use of the Quality of Well-Being scale, which has been validated for cost-effectiveness analysis. Costs are facility charges per the facility cost-to-charges ratio plus surgeon fee. Sensitivity analyses are performed to determine the effect of variations in costs or outcomes. **Results:** There were 93 knee arthroscopy and 35 ACL reconstruction patients included at a mean follow-up of 2.1 years. Cost per QALY was $5,783 for arthroscopy and $10,326 for ACL reconstruction (2009 US dollars). Sensitivity analysis shows that our results are robust (relatively insensitive) to variations in costs or outcomes. **Conclusions:** Knee arthroscopy and knee ACL reconstruction are very cost-effective. **Level of Evidence:** Level I, economic analysis (sensible costs with multiway sensitivity analyses).

Health care cost is a topical challenge. A proactive, academic response is medical cost-effectiveness research. Cost-effectiveness research methods integrate (1) measurements of change in health-related quality of life after medical intervention, (2) duration of life expectancy, and (3) cost of treatment. These variables allow calculation of the cost of a quality-adjusted life-year (QALY).

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The QALY is "a standard measure of health-related quality of life in medical cost-effectiveness research,"[1,2] and the cost of a QALY may be used to compare the cost-effectiveness or value of diverse medical treatments. Cost-effective treatments have lower costs per QALY. It is possible to rank the cost-effectiveness of different treatments in league tables, like a sports league, by comparing costs per QALY of different treatments.

Knee arthroscopy, by volume, is the most common procedure performed by applicants for part II of the American Board of Orthopaedic Surgery's certification examination.[3] Knee anterior cruciate ligament (ACL) reconstruction is the sixth most common procedure on this list (or fifth most common when knee arthroscopic meniscectomy [first on the list] and knee arthroscopic chondroplasty [fourth on the list] are combined). However, the cost-effectiveness of knee arthroscopy has not been reported.

Gottlob et al.[4,5] evaluated the cost-effectiveness of ACL reconstruction and found that it was "highly cost effective." A limitation of the studies by Gottlob et al.

is their research method; outcome was determined by literature review rather than evaluation of actual patients. In addition, only data from "young adults in their late teens and 20s" were reported. Gottlob et al. recommended future research evaluating other patient populations.

The purpose of this study was to determine the cost-effectiveness of both knee arthroscopy and knee ACL reconstruction in patients of all ages. Our hypothesis was that knee arthroscopy and ACL reconstruction are very cost-effective procedures.

## METHODS

Our primary outcome measure was cost-effectiveness (cost of a QALY). We measured the cost-effectiveness of 2 conditions: (1) knee arthroscopy and (2) knee ACL reconstruction. Costs were defined as the sum of facility (hospital or surgery center) costs plus the surgical professional fee.[6] Facility costs were calculated by dividing facility charges by the facility cost-to-charges ratio (by cost-effectiveness analysis convention and to adjust for the substantial differences between actual facility costs and the substantially higher fees that facilities charge).[6]

Relevant to the hypothesis, "very cost-effective procedures" have a cost per QALY of less than $29,300, as defined by Laupacis et al.[7] in the *Canadian Medical Association Journal* in 1992. (All costs in this article are reported in 2009 US dollars [USD] adjusted for inflation,[8] and Canadian dollars are converted to USD through a 1 USD–to–1.03 Canadian dollars ratio.[9])

QALYs were determined by multiplying the difference in health-related quality-of-life scores, before and after treatment, by life expectancy. Health-related quality of life is measured with the self-administered Quality of Well-Being (QWB) scale,[1,10] "one of the few instruments that can help calculate QALY as an expression of health outcome."[1] The QWB scale "is extensively validated and its psychometric properties are well established"[1,11] for cost-effectiveness analysis. Life expectancy is calculated by use of US Centers for Disease Control and Prevention life tables.[12]

In summary, the primary outcome measure for knee arthroscopy and ACL reconstruction is cost per QALY:

Cost/QALY = [(Facility charges/Facility cost-to-charges ratio) + Surgical professional fee]/[(Postoperative QWB – Preoperative QWB) × Life expectancy].

### Patient Inclusion and Exclusion Criteria

After institutional review board approval; establishment of a confidential, secure single-surgeon database; and patient (or guardian) informed consent, we retrospectively analyzed our prospectively collected database and identified and included 128 consecutively treated patients, of all ages, who completed preoperative and 2-year postoperative QWB scale scores, with patient loss to follow-up of less than 20%.

Knee arthroscopy patients were defined as those having any or all of the following arthroscopic procedures: chondroplasty, lateral meniscectomy, lateral meniscus repair, lateral retinacular release, loose body removal, medial meniscectomy, medial meniscus repair, microfracture, or synovectomy. Patients having ligament reconstruction, chondrocyte or osteochondral transplantation, or concomitant open knee surgery were excluded.

ACL reconstruction patients were defined as those having primary or revision ACL reconstruction by any method. Included were patients having additional knee arthroscopy procedures as defined previously. Excluded were patients having concomitant chondrocyte or osteochondral transplantation, concomitant open knee surgery, or multiligament reconstruction.

### Sensitivity Analysis

To ensure generalizability of cost data, 1-way sensitivity analysis was performed to determine the effect of quantitative variation of the procedure cost. To ensure against sampling bias undermining a health-related quality-of-life score change after surgery, 1-way sensitivity analysis was performed to determine the effect of quantitative variation of the change in QWB scale scores.

### Checklist for Reporting Cost-Effectiveness Analysis

During preparation of this report, the US Public Health Service's Panel of Cost-Effectiveness in Health and Medicine recommendations and Checklist for Reporting the Reference Case Cost-Effectiveness Analysis were observed.[13]

### Statistical Methods

The formula for calculating cost per QALY was described previously.

**TABLE 1.** *Preoperative and Postoperative QWB Scale Scores and Improvement in QWB Scale Scores by Cohort*

| | Preoperative QWB | Postoperative QWB | Improvement in QWB |
|---|---|---|---|
| Knee arthroscopy | 0.672 (0.648 to 0.697) | 0.704 (0.680 to 0.729) | 0.032 (0.014 to 0.050) |
| ACL reconstruction | 0.690 (0.659 to 0.722) | 0.721 (0.687 to 0.755) | 0.031 (−0.006 to 0.067) |

NOTE. The 95% confidence interval is shown in parentheses. A negative value in the confidence interval for improvement in QWB indicates that some patients did not improve.

## RESULTS

One hundred twenty-eight patients were included. All were community hospital day-surgery outpatients. Eighty percent of patients (102 of 128) completed follow-up at a mean of 2.2 years.

### Knee Arthroscopy

Ninety-three patients underwent knee arthroscopy. The mean patient age was 43.9 years (range, 11 to 79 years), and male patients comprised 56%. Specific knee arthroscopy procedures include the following (the percentages add up to >100% because of multiple procedures in individual patients): chondroplasty, 84%; lateral meniscectomy, 41%; lateral meniscus repair, 0%; lateral retinacular release, 14%; loose body removal, 22%; medial meniscectomy, 54%; medial meniscus repair, 1%; microfracture, 5%; and synovectomy, 38%.

### ACL Reconstruction

Thirty-five patients had ACL reconstruction. The mean patient age was 38.2 years (range, 13 to 66 years), and male patients comprised 56%.

Specific ACL reconstruction cohort procedures include the following (the percentages add to >100% because of multiple procedures in individual patients): ACL primary reconstruction, 97%; ACL revision reconstruction, 3%; chondroplasty, 26%; lateral meniscectomy, 74%; lateral meniscus repair, 9%, lateral retinacular release, 0%; loose body removal, 17%; medial meniscectomy, 37%; medial meniscus repair, 26%; microfracture, 3%; and synovectomy, 0%. Specific ACL graft types were allograft (66%), hamstring tendon autograft (14%), and patellar tendon autograft (20%).

### Life Expectancy

Overall, mean years of life remaining was 35.7 years (range, –1.0 to 67 years; a negative number represents that some included patients exceeded the mean life expectancy of 77.7 years). Mean years of life remaining was 34.1 years (range, –1.0 to 67 years) for knee arthroscopy patients. Mean years of life remaining was 39.8 years (range, 12 to 65 years) for ACL reconstruction patients.

### Health-Related Quality of Life

Mean improvement on the QWB scale was 0.032 (95% confidence interval [CI], 0.015 to 0.048). Mean improvement in QWB was 0.032 (95% CI, 0.014 to 0.050) for knee arthroscopy and 0.031 (95% CI, −0.006 to 0.067; a negative number represents that some patients did not improve) for ACL reconstruction. QWB data are summarized in Table 1.

### Costs

Mean total procedure cost was $6,310 for knee arthroscopy and $12,740 for ACL reconstruction. Cost data are summarized in Table 2. The hospital's Chief Financial Officer provided hospital cost data but would not disclose hospital charges or the hospital cost-to-charges ratio, which is common because hospitals do not prefer to reveal this ratio, or "mark-up," which results in large differences between actual facility costs and the substantially higher fees that facilities charge.

### Cost-Effectiveness

Cost per QALY was $5,783 for knee arthroscopy and $10,326 for ACL reconstruction. Cost-effectiveness data are summarized in Table 2.

**TABLE 2.** *Hospital Cost, Surgical Professional Fee, Total Cost, and Cost per QALY by Cohort, Adjusted for Inflation[8] to Represent 2009 USD*

| | Hospital Cost | Professional Fee | Total Cost | Cost/ QALY |
|---|---|---|---|---|
| Knee arthroscopy | $1,060 | $5,250 | $6,310 | $5,783 |
| ACL reconstruction | $1,740 | $11,000 | $12,740 | $10,326 |

### Sensitivity Analysis

To determine the effect of variation of procedure cost, 1-way sensitivity analysis was performed. As procedure cost increases, cost per QALY increases. Yet, even if procedure cost more than doubled, both arthroscopy and ACL reconstruction would remain very cost-effective (cost per QALY <$29,300). The sensitivity of procedure cost is illustrated in Fig 1.

To adjust for the possibility of bias affecting measurement of improvement in health, 1-way sensitivity analysis was performed to determine the effect of variation of improvement in QWB scale scores after surgery. As improvement in QWB after surgery decreases, cost per QALY increases. Yet, even if improvement in QWB scale scores more than halved, both arthroscopy and ACL reconstruction would remain very cost-effective (cost per QALY <$29,300). The sensitivity of improvement in QWB is illustrated in Fig 2.

## DISCUSSION

Our results show that the cost-effectiveness (cost per QALY) of knee arthroscopy is $5,783 and that of ACL reconstruction is $10,326. Our hypothesis is supported: both procedures are very cost-effective (cost per QALY <$29,300).

The cost-effectiveness of knee arthroscopy has not previously been reported. The cost-effectiveness of ACL surgery has been previously reported by Gottlob et al.[4,5] as $12,100 (adjusted for inflation from 1999 USD to 2009 USD). Although Gottlob et al. used analytic modeling methods and considered only young patients, whereas we used prospectively collected clinical outcome data from patients of all ages, our results are similar. Our result shows greater cost-effectiveness, and both results show that ACL surgery is very cost-effective.

Cost-effectiveness rankings allow comparison of different medical treatments, where treatments with lower costs per QALY maximize the benefits to patients per unit of cost.[14,15] To facilitate comparison, by convention, these rankings must be adjusted for inflation by date and for currency.[13] A ranking of cost-effectiveness of different medical treatments in 2009 USD is reported in Table 3.[4,5,6,14,16-18] Because studies use similar but not identical methods, reporting bias must be considered when one is comparing the relative cost-effectiveness.[5,16,17]

Knee arthroscopy and knee ACL reconstruction are near the top of the league table. According to the Panel

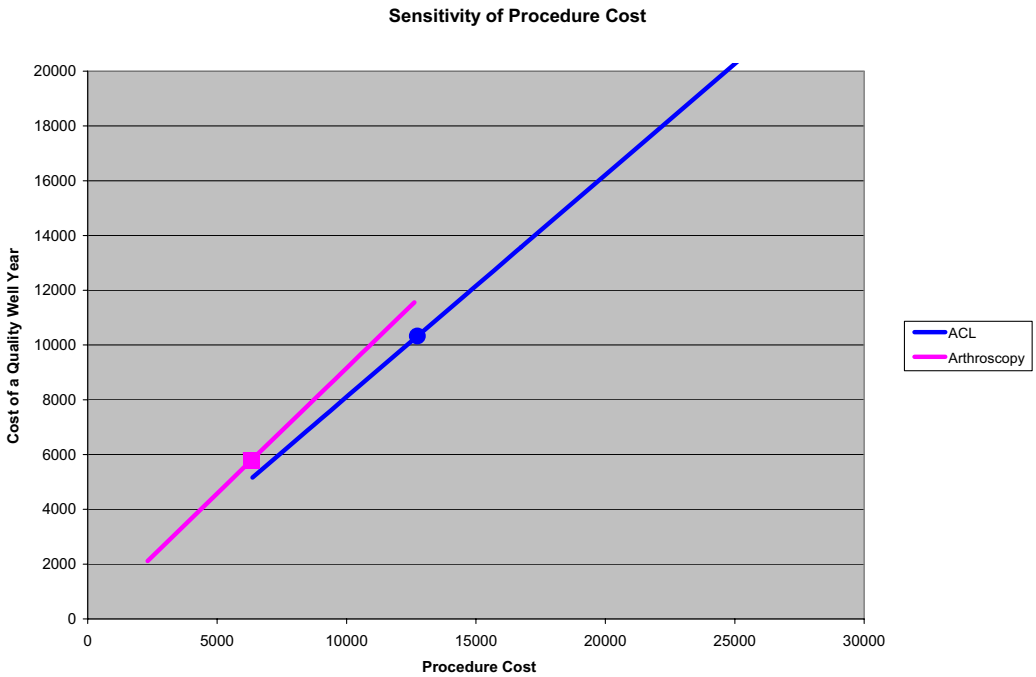


FIGURE 1. One-way sensitivity analysis of quantitative variation of procedure cost on cost per QALY. Knee arthroscopy (pink line, with reference result indicated by square) and ACL reconstruction (blue line, with reference result indicated by circle) remain very cost-effective (cost per QALY <$29,300)[7] even if procedure costs are more than doubled.

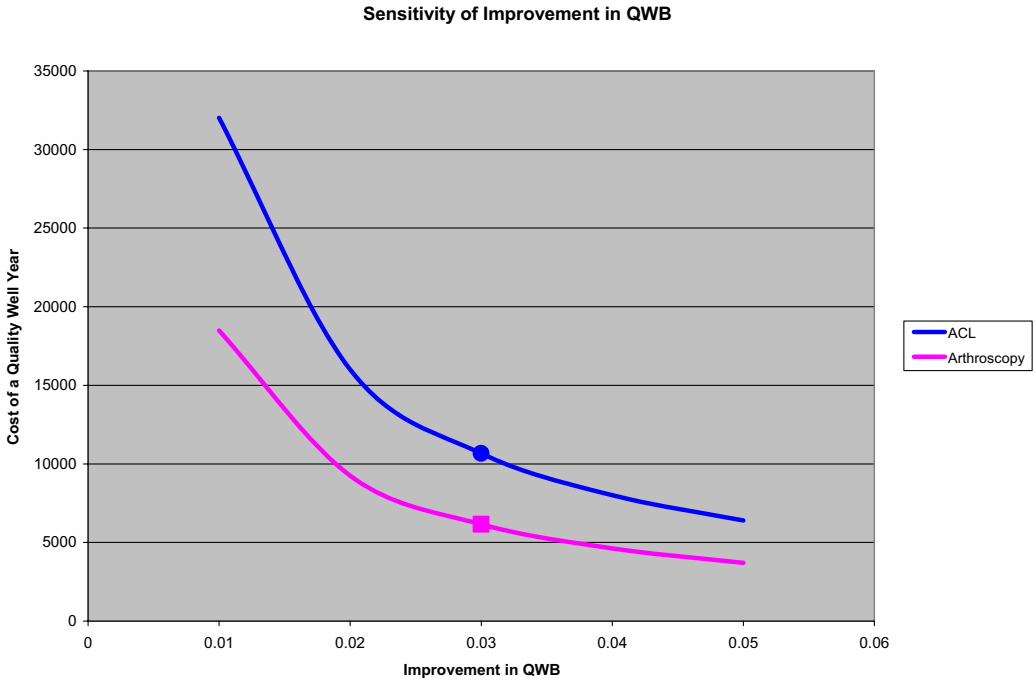


**FIGURE 2.** One-way sensitivity analysis of quantitative variation of improvement in QWB scale score on cost per QALY. Knee arthroscopy (pink line, with reference result indicated by square) and ACL reconstruction (blue line, with reference result indicated by circle) remain very cost-effective (cost per QALY <$29,300)[7] even if improvement after surgery decreases by more than half.

of Cost-Effectiveness in Health and Medicine convened by the US Public Health Service, "because cost-effectiveness is relative . . . interventions are better described as being more or less cost-effective than others"[13]; following this recommendation, we describe knee arthroscopy and ACL reconstruction as more cost-effective than medical treatments listed below knee arthroscopy and ACL reconstruction in the rankings (Table 3).

A limitation of our study is that ethical problems may arise from analysis assumptions.[13] Our methods maximize aggregate benefits to patients,[14,15] but some clinicians and policy administrators have other priorities. For example, some believe that "absolute priority should be given to the worst off when making social choices affecting basic needs."[19] Similarly, some adhere to the Rule of Rescue, stating that it is more important to prevent loss of life than to improve health-related quality of life.[20] According to the Department of Ethics of the US National Institutes of Health (2009), "no single principle is sufficient to incorporate all morally relevant considerations"; 4 categories of principles must be combined: "treating people equally, favoring the worst-off, maximizing total benefits, and promoting and rewarding social usefulness."[21] We accord the last words on cost-effectiveness analysis, again, to the Panel of Cost-Effectiveness in Health and Medicine convened by the US Public Health Service: "Although CES [cost-effectiveness analysis] does not reflect every element of importance in health care decisions, the information it provides is critical to informing decisions about the allocation of health care resources."[22]

Additional limitations of our study include imprecision in measurement of health-related quality of life for economic appraisal. Imprecision "can be, to some extent, ameliorated through . . . careful use of sensitivity analysis."[16] In our investigation, results were not sensitive to variations in changes in QWB after arthroscopy (Fig 2). Performance bias was minimized because each procedure was performed by a single surgeon. Susceptibility bias was minimized by creating separate cohorts of patients (knee arthroscopy and ACL reconstruction) with similar prognoses. Yet, within these cohorts, we include diverse ages of patients and procedures; therefore our results are generalizable. However, limitations exist when applying general results to a specific patient procedure. Sensitivity analysis (Fig 2) also ameliorates performance and susceptibility bias. Reporting bias is minimized by use of validated outcome measures. An additional limitation of our study is that cost-effectiveness of nonoperative management was not evaluat-

**TABLE 3.** *Ranking of Cost-Effectiveness per QALY of Different Medical Treatments Adjusted for Inflation[8] to Represent 2009 USD*

| Treatment | Cost/QALY |
|---|---|
| Phenylketonuria screening[16] | $1,100 |
| Postpartum anti-D immunoglobulin[16] | $1,100 |
| Antepartum anti-D immunoglobulin[16] | $2,630 |
| Knee arthroscopy—reference case data | $5,783 |
| Coronary artery bypass surgery for left main coronary artery disease[16] | $9,050 |
| Total knee replacement arthroplasty[6] | $9,680 |
| Neonatal intensive care, 1,000-1,499 g[16] | $9,690 |
| ACL reconstruction—reference case data | $10,326 |
| ACL reconstruction—previously published data[4,5] | $12,100 |
| Thyroid (T4) screening[16] | $13,600 |
| Total knee replacement arthroplasty[18] | $18,700 |
| Treatment of severe hypertension (diastolic blood pressure ≥105 mm Hg) in men aged 40 yr[16] | $20,200 |
| Treatment of mild hypertension (diastolic blood pressure ≥95-104 mm Hg) in men aged 40 yr[16] | $41,200 |
| Estrogen therapy for postmenopausal symptoms in women without prior hysterectomy[16] | $58,200 |
| Neonatal intensive care, 500-999 g[16] | $68,500 |
| Coronary artery bypass surgery for single-vessel disease with mildly severe angina[16] | $78,200 |
| School tuberculin testing program[16] | $94,100 |
| Continuous ambulatory peritoneal dialysis[16] | $101,000 |
| Hospital hemodialysis | $116,000 |

NOTE. Reference case data (representing our study results) are reported, along with additional data from previous references as indicated. ACL reconstruction is listed twice, indicating both reference data and previously published data.[4,5] Total knee replacement arthroplasty is listed twice, indicating different cost-effectiveness reported in two previously published studies.[6,18] Treatments with lower costs per QALY maximize the benefits to patients per unit of cost.[14] Treatments with a cost per QALY of less than $29,300 (2009 USD) are defined as very cost-effective.[7] Because studies use similar but not identical methods, reporting bias must be considered when one is comparing the relative cost-effectiveness.[5,16,17]

ed[23,24]; nonoperative treatment of ACL injury has previously been reported to be very cost-effective yet not without expense.[5]

## CONCLUSIONS

Knee arthroscopy and knee ACL reconstruction are very cost-effective.

## REFERENCES


1. Siebert WJ, Groessl EJ, David KM, Ganiats TG, Kaplan RM. Quality of Well Being Self-Administered (QWB-SA) scale. San Diego: Health Services Research Center, University of California, 2008. Available from: http://hoap.ucsd.edu/qwb-info/QWB-Manual.pdf. Accessed October 24, 2009.
2. Gold M, Franks P, Erickson P. Assessing the health of the nation. The predictive validity of a preference-based measure and self-rated health. *Med Care* 1996;34:163-177.
3. Garrett WE, Swiontkowski MF, Weinstein JN, et al. American Board of Orthopaedic Surgery Practice of the Orthopaedic Surgeon: Part-II, certification examination case mix. *J Bone Joint Surg Am* 2006;88:660-667.
4. Gottlob CA, Baker CL Jr, Pellissier JM, Colvin L. Cost effectiveness of anterior cruciate ligament reconstruction in young adults. *Clin Orthop Relat Res* 1999;367:272-282.
5. Gottlob CA, Baker CL. Anterior cruciate ligament reconstruction: Socioeconomic issues and cost-effectiveness. *Am J Orthop (Belle Mead NJ)* 2000;29:472-476.
6. Lavernia CJ, Guzman JF, Gachupin-Garcia A. Cost effectiveness and quality of life in knee arthroplasty. *Clin Orthop Relat Res* 1997;345:134-139.
7. Laupacis A, Feeny D, Detsky AS, Tugwell PX. How attractive does a new technology have to be to warrant adoption and utilization? Tentative guidelines for using clinical and economic evaluations. *CMAJ* 1992;146:473-481.
8. Purchasing power calculator. Available from: http://www.measuringworth.com/ppowerus/. Accessed August 16, 2010.
9. Currency conversion calculation. Available from: http://www.google.com/search?client=firefox-a&rls=org.mozilla%3Aen-US%3Aofficial&channel=s&hl=en&source=hp&q=us+dollar+to+canadian+dollar&btnG=Google+Search. Accessed October 20, 2009.
10. Kaplan RM, Bush JW, Berry CC. Health status: Types of validity and the index of well-being. *Health Serv Res* 1976;11:478-507.
11. Kaplan RM, Anderson JP, Ganiats TG. The Quality of Well Being Scale: Rationale for a single quality of life index. In: Walker SR, Rosser RM, eds. *Quality of life assessment: Key issues in the 1990s*. London: Kluwer Academic Publishers, 1993;65-94.
12. Life expectancy. Centers for Disease Control and Prevention. Available from: http://www.cdc.gov/nchs/fastats/lifexpec.htm. Accessed October 3, 2009.
13. Siegel JE, Weinstein MC, Russell LB, Gold MR. Recommendations for reporting cost-effectiveness analyses. Panel on Cost-Effectiveness in Health and Medicine. *JAMA* 1996;276:1339-1341.
14. James M, St. Leger S, Rowsell KV. Prioritising elective care: A cost utility analysis of orthopaedics in the north west of England. *J Epidemiol Community Health* 1996;50:182-189.
15. Detsky AS, Naglie IG. A clinician's guide to cost-effectiveness analysis. *Ann Intern Med* 1990;113:147-154.
16. Torrance GW. Measurement of health state utilities for economic appraisal. *J Health Econ* 1986;5:1-30.
17. Mason J, Drummond M, Torrance G. Some guidelines on the use of cost effectiveness league tables. *BMJ* 1993;306:570-572.
18. Losina E, Walensky RP, Kessler CL, et al. Cost-effectiveness of total knee arthroplasty in the United States: Patient risk and hospital volume. *Arch Intern Med* 2009;169:1113-1121.
19. Cohen BJ. Assigning values to intermediate health states for cost-utility analysis: Theory and practice. *Med Decis Making* 1996;16:376-385.
20. Hadorn DC. Setting health care priorities in Oregon. Cost-effectiveness meets the rule of rescue. *JAMA* 1991;265:2218-2225.
21. Persad G, Wertheimer A, Emanuel EJ. Principles for allocation of scarce medical interventions. *Lancet* 2009;373:423-431.
22. Russell LB, Gold MR, Siegel JE, Daniels N, Weinstein MC. The role of cost-effectiveness analysis in health and medicine. Panel on Cost-Effectiveness in Health and Medicine. *JAMA* 1996;276:1172-1177.
23. Frobell RB, Roos EM, Roos HP, Ranstam J, Lohmander LS. A randomized trial of treatment for acute anterior cruciate ligament tears. *N Engl J Med* 2010;363:331-342.
24. Levy BA. Is early reconstruction necessary for all anterior cruciate ligament tears? *N Engl J Med* 2010;363:386-388.