TITLE PAGE

Title: Diverse approaches to the health economic evaluation of bariatric surgery: a comprehensive systematic review.

Julie A. Campbell¹, Alison Venn¹, Amanda Neil¹, Martin Hensher², Melanie Sharman¹, and Andrew J. Palmer¹.

1. Menzies Institute for Medical Research, University of Tasmania, Medical Sciences 2 Building, 17 Liverpool Street, Hobart, Tasmania, Australia, 7000.
2. Department of Health and Human Services, Level 5, 24 Davey Street, Hobart, Tasmania, Australia, 7000.

Keywords: Bariatric/metabolic surgery, health economic evaluation, diabetes, body contouring surgery, waiting list.

Running Title: Health economic evaluation of bariatric surgery.

Corresponding Author:

Professor Andrew J. Palmer

Founding Chair, Health Economics

Menzies Institute for Medical Research, University of Tasmania

Medical Sciences 2 Building

17 Liverpool St Hobart 7000

Tasmania, Australia

Email: Andrew.Palmer@utas.edu.au

Tel: +61 (0) 3 62267729

Email addresses of all authors:

Julie.Campbell@utas.edu.au

Alison.Venn@utas.edu.au

Amanda.Neil@utas.edu.au

Martin.Hensher@dhhs.tas.gov.au

This is the author manuscript accepted for publication and has undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the Version of Record. Please cite this article as doi: 10.1111/obr.12424

Melanie.Sharman@utas.edu.au

Andrew.Palmer@utas.edu.au

Author Manuscript

MANUSCRIPT TEXT

Abstract

Background: Health economic evaluations inform healthcare resource allocation decisions for treatment options for obesity including bariatric/metabolic surgery. As an important advance on existing systematic reviews, we aimed to capture, summarise and synthesise a diverse range of economic evaluations on bariatric surgery. **Methods:** Studies identified by electronic screening of all major biomedical/economic databases. Studies included if they reported any quantified health economic cost and/or consequence with a measure of effect for any type of bariatric surgery from 1995 to September 2015. Study screening, data extraction and synthesis followed international guidelines for systematic reviews. **Results:** 6182 studies initially identified. After two levels of screening, 77 studies representing 17 countries (55% United States) were included. Despite study heterogeneity, common themes emerged and important gaps were identified. Most studies adopted the health-care system/third-party payer perspective, reported costs were generally healthcare resource use (inpatient/shorter term outpatient). Out-of-pocket costs to individuals, family members (travel-time, care-giving) and indirect costs due to lost productivity were largely ignored. Costs due to reoperations/complications were not included in one-third of studies. Body-contouring surgery included in only 14%. One study evaluated long-term waitlisted patients. Surgery was cost-effective/cost-saving for severely obese with type 2 diabetes (T2DM). Study quality was inconsistent. **Discussion:** There is a need for studies that assume a broader societal perspective (including out-of-pocket costs, costs to family, productivity losses) and longer-term costs (capture reoperations/complications, waiting, body-contouring), and consequences (health-

related quality-of-life). Full economic evaluation underpinned by reporting standards should inform prioritisation of patients (e.g. T2DM with body mass index 30 to 34.9 kg/m² or long-term waitlisted) for surgery.

MANUSCRIPT TEXT

Abbreviations

Body mass index (BMI); Organisation for Economic Co-operation and Development (OECD); type 2 diabetes mellitus (T2DM); Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA); Campbell and Cochrane Economics Methods Group (CCEMG); Consolidated Health Economic Reporting Standards (CHEERS); Medical Subject Headings (MeSH); laparoscopic adjustable gastric banding (LAGB); Swedish adjustable gastric banding (SAGB); vertical gastric banding (VB); gastric banding (GB); vertical banded gastroplasty (VBG); sleeve gastrectomy (SG); gastric bypass (GBP); Roux-en-Y gastric bypass (RYGBP); randomised control trial (RCT); cardio-vascular disease (CVD).

Introduction

The health and economic burden of obesity

Obesity is not only a major health concern, it is also an economic problem (1). Excess weight gain is forecast to lead to an increased health burden from several diseases, most notably cardiovascular diseases, diabetes and cancers (1). The economic burden of the obesity epidemic is substantial and far-reaching and includes the increase in medical and other obesity-related expenditures (1), decreased workplace productivity (2), negative impacts on family and

relationships (3) and stigmatisation and discrimination of the overweight and obese both individually and collectively (4).

Overweight and obesity in adults is commonly classified with body mass index (BMI) calculated as $BMI = \text{weight (kg)} / \text{height (m}^2\text{)}$. For adults $BMI \geq 25 \text{ kg/m}^2$ is classified as overweight and $BMI \geq 30 \text{ kg/m}^2$ is obesity (5). Worldwide prevalence of obesity has doubled since 1980 (5) and based on latest available surveys, more than half (53%) of the adult population in the Organisation for Economic Co-operation and Development (OECD) is estimated to be overweight or obese (6). Among those countries where height and weight were measured, the proportion was even greater at 57% (6). Furthermore, severe obesity ($BMI \geq 35 \text{ kg/m}^2$) is increasing faster than obesity in adults and children (7).

A recent ground-breaking econometric study suggests that self-reported weight consistently underestimates the effects on government costs (8). The study adopted the econometric instrumental variables approach to investigate the causal effect of obesity on medical care costs by adjusting for endogeneity of weight (the correlation of obesity with medical care costs where the model may be informed by an under or over estimate of costs) and measurement error in weight (replace self-reported height and weight) (8). Importantly, this study implied that previous widely-cited estimates have underestimated the causal impact of obesity on medical care costs. In turn, this implies underestimates of the economic rationale for government intervention to reduce obesity related costs (8). Treatments for overweight and obesity include dietary therapy, exercise/behavioural interventions, weight loss medications and bariatric (weight loss/metabolic (9)) surgery (10). Bariatric surgery is a well-documented treatment for obesity worldwide with increasing prevalence in developed and developing

countries and the types of metabolic/bariatric operations are in continuous flux with different surgical options continuously evolving influenced by literature results, specific local conditions and the experience of surgical staff (11-13). Many clinical and epidemiological studies have found that all types of bariatric surgery are clinically effective particularly for patient subgroups such as the severely obese and severely obese with type 2 diabetes mellitus (T2DM) (14). As a rapidly evolving subspecialty of gastrointestinal surgery, bariatric surgical procedures involve gastric restriction (to augment early satiety and limit meal portions) or intestinal diversion (designed to reduce caloric absorption). Some bariatric procedures contain elements of restriction and diversion (15). Bariatric medicine has developed as a clinical subspecialty in some countries and others are calling for this level of specialisation as a treatment option for obesity (16).

Economic evaluation of bariatric surgery

Economics is a discipline concerned with the existence of limited resources and unlimited human wants and desires. Without enough resources to satisfy all the desires of all people, the challenge arises how to allocate those available resources among competing objectives (17).

Economic evaluation is defined as “*the comparative analysis of alternative courses of action in terms of both their costs and consequences*”. Economic evaluation is a vital resource allocation methodology because it provides decision-makers with robust analyses to underpin decisions about committing scarce healthcare resources to one use instead of another (18). An economic evaluation needs to identify, measure, value and compare the costs and consequences of the alternatives being considered (18).

A recent study that investigated the incorporation of economic evidence and perspectives in Cochrane reviews argued that questions such as “at what cost is the outcome achieved?”, and “what will be the economic impact of this intervention?” are crucial if health systems are to use the resources they have available to their best advantage (19). Many full economic evaluations conclude that bariatric procedures are a cost-effective treatment option for obesity (20-26). In contrast, a recent critique opined that accumulating evidence suggested no economic benefit for bariatric surgery (27). The critique also called for the consideration of patients who have a complication of obesity that was known to dramatically improve with weight loss surgery (e.g. diabetes and osteoarthritis) (27). Further, for an intervention to be cost-effective, ability as well as willingness to pay must be met. The aim of this systematic review is to explore these conflicting observations.

Specifically, our systematic review aims to: map what research has been conducted; identify common themes amongst heterogeneous studies; identify the major ‘knowledge gaps’ (28) by classifying and critically analysing variables that underpin both partial and full economic evaluation and by detailed investigation of the health economic metrics of full economic evaluation; and describe the overall quality of the research. It will also identify patient subgroups where bariatric surgery is found to be largely cost-effective and patient subgroups that warrant further health economic investigation. To date, systematic reviews of health economic outcomes for bariatric surgery have generally adopted narrow eligibility criteria and reported on limited primary studies, or have selected homogenous studies to retrieve data to model cost-effectiveness (15, 29-32). Other systematic reviews have restricted eligibility by assuming criteria such as long-term modelling of cost-effectiveness (33). As an important

advance on existing systematic reviews, our review adopts broad eligibility criteria to capture a disparate and comprehensive range of health economics studies that have investigated bariatric surgery as a treatment option for obesity.

Methods

Validated guidelines

This systematic review has been performed and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (34). The Campbell and Cochrane Economics Methods Group (CCEMG) guidelines to incorporating economic evidence in reviews informed the bibliographic database search criteria, data extraction and synthesis (35).

No previous systematic review has critically appraised health economics evaluations for bariatric surgery for methodological quality against the Consolidated Health Economic Reporting Standards (CHEERS) statement (36). The CHEERS statement consolidates previous health economics evaluation guidelines into one current useful reporting guidance and recognises that economic evaluations require additional reporting space (36). Included studies were graded as high, medium and low quality. All of the 24 items were given equal weight. For full economic evaluations, 20-24 points of the 24 point checklist were categorised as high quality, 15-19 points were deemed to be of medium quality and ≤ 14 points ranked as low quality ($< 60\%$). Methodological quality of partial economic evaluations was also considered and percentages were calculated on a pro-rata basis where $< 60\%$ of the relevant CHEERS

statement for the particular study was rated low quality, 60 - 80% medium quality and > 80% high quality.

Bibliographic databases and search terms

A predefined search strategy was used to identify relevant articles published in both health economics and biomedical databases from 1995 to September 2015. Seven economic databases - American Economic Association (EconLit), Ideas, the Centre for Reviews and Dissemination (CRD) which includes the Database of Abstracts of Reviews of Effects (DARE), Health Technology Database (HTA), NHS Economic Evaluation Database (NHS EED) and the Cost-Effectiveness Registry (CEA Registry) and four biomedical databases - PubMed, MEDLINE, Embase and Scopus were initially searched between June – September 2014. A further search was conducted in September 2015 to capture studies from September 2014 to September 2015. Search terms were adopted from the databases' vocabulary tools where available such as Medical Subject Headings (MeSH terms) for PubMed/MEDLINE including 'health care economics and organizations' and 'bariatric surgery' and 'quality of life' and Emtree terms for EMBASE including 'bariatric surgery, 'economic aspect' and 'quality of life'. Scopus and the economic databases do not contain vocabulary tools and the appropriate search terms were grouped together adopting the PICO convention which references participants, interventions, comparisons and outcomes (37). An example of the search strategy is provided in Table 1. To identify other relevant studies, a key word search of Google Scholar, citation lists and the bibliographies of review articles and the obtained studies were also scrutinised.

Study eligibility, selection of studies and data extraction

Studies were included if they satisfied the following criteria: 1) reported a quantified cost and/or consequence with a measure of effect for no surgery, 'before and after', conventional treatment or standard care (studies that only compared costs of one type of surgery against another type were excluded), for any type of bariatric surgery such as laparoscopic adjustable gastric banding (LAGB), Swedish adjustable gastric banding (SAGB), vertical gastric banding (VB), gastric banding (GB), vertical banded gastroplasty (VBG), sleeve gastrectomy (SG), gastric bypass (GBP) and Roux-en-Y gastric bypass (RYGBP); 2) reported in English in the scholarly literature; and 3) participants include adults, adolescents or children. Other systematic reviews, studies that report health-related quality of life or health state utility only and studies that do not report an effect were excluded.

From the initial yield, search results were put through two levels of screening prior to data extraction. Initial screening was open-ended to retain as many relevant studies as possible. Titles and abstracts were screened for evidence of health economic analyses including cost and cost analysis, cost-effectiveness analysis, cost-utility analysis and cost-benefit analysis, or health economics metrics such as changes in costs before and after surgery, costs per quality adjusted life year, costs per life year saved, costs per disability adjusted life year, time to breakeven or quantified changes in work productivity. A random sample of included and excluded studies after the initial screening was independently reviewed by two co-authors. After removing studies that fit the exclusion criteria during the first level of screening the full text of the remaining studies was assessed against the inclusion criteria and any disagreements were resolved by consensus.

Data Extraction

Data were extracted on authorship, year of origin, country of origin, type of bariatric surgery, study design, sample size, study population, discount rate, classification of studies as partial or full economic evaluations, health economics perspective (health-care system/third-party payer, societal, not stated), time horizon, comparator (including before and after surgery), currency, clinical effectiveness measures, costs including costs of the initial procedure, health-care resource use (hospital and community care), patient and family (out-of pocket expenses (excluding direct medical, travel time, direct care giving)), resource use in other sectors (including work productivity and pension status), cost-effectiveness and cost-utility metrics (e.g. incremental cost/QALY gained, cost/life-year saved, cost/case T2DM remitted), reoperations, complications or body contouring surgery were also reported separately, and key summary measure(s) and key conclusion(s).

The definitions of partial and full economic evaluations, willingness to pay thresholds, health economics perspective and costs were derived from standard health economics sources (18, 38). Reoperations and complications were classified as any re-operative/revisional procedure or complication following the primary procedure (including peri-operative complications).

Results

Screening for study eligibility

The electronic search yielded 6182 studies. Biomedical databases generated 5940 studies and economic databases generated 241 studies. A further 6 studies were identified through other sources. After removal of duplicates 4474 studies' titles and abstracts were reviewed against the eligibility criteria and 4216 studies were excluded. 258 full text articles were then assessed

for eligibility and 181 were excluded leaving 77 included studies. Figure 1 provides results of the search strategy based on PRISMA methodology.

Overlap with previous systematic reviews

The six previously-performed health economic systematic reviews contained 29 studies. Our review contained 21 of these studies: the other eight did not satisfy our broad eligibility criteria. Twenty-one of these studies were published before 2009 and 16 of these studies were cost-effectiveness or cost-utility studies. Our review included 46 studies from 2010 to 2014, 18 of these studies were full economic evaluations and 28 were partial economic evaluations (eight of the full economic evaluations were included in the previously-performed studies).

Overview and synthesis of included studies

A comprehensive description of the characteristics of the all included studies is shown in Table 2. Subgroup analyses of included cost-effectiveness and cost-utility studies from 2009 stratified into diabetes cohort specific studies and severe obesity cohort/s studies are provided in Tables 3A and 3B respectively. Willingness to pay thresholds for different jurisdictions are reported in Table 4. *Distribution of region and type of surgery*

Fifty five percent (n=42) of studies originated from the United States (2, 10, 20, 22, 26, 39-76). Studies also originated from Sweden (24, 77-83) 10% (n=8), Australia (84-89) 8% (n=6), United Kingdom (90-95) 8% (n=6), Canada (62, 96, 97) 4% (n=3), and the remainder of the included studies each for France (90, 98) (n=2), Germany (90), (Austria, Italy, Spain) (99), Spain (21), Norway (100), Portugal (101), The Netherlands (102, 103), Finland (25), South

Korea (104), Brazil (105, 106) (n=2), and Mexico (107). Two studies reported data from three countries (90, 99) (Table 2).

Reporting of bariatric procedures has evolved according to the relative distribution of procedures for the timeframe (11, 13). In line with technical change (11, 108), included studies from 1995 to early 2000 largely reported on open procedures such as RYGBP, VBG and GBP. Laparoscopic procedures such as LAGB and laparoscopic Roux-en-Y gastric bypass (LRYGBP) are reported from the early 2000s (Table 2).

Time horizon

Seventy six studies reported a time horizon. Of those that reported a time horizon, 42% (n=32) adopted a timeframe of ≤ 5 years (2, 41-46, 49-51, 53, 58, 61, 65, 68, 69, 73, 77, 85, 87, 88, 90-92, 94-100, 103, 105, 106) and 53% of these studies reported results for ≤ 2 years (n=17) (41-46, 49, 50, 53, 69, 73, 85, 91, 94, 95, 100, 103, 105) (mostly cost and cost analyses). Some cost and cost analyses reported a longer time horizon of 6-10 years (n=12, 16%) (39, 48, 57, 60, 66, 67, 70, 71, 74, 75, 79, 80), or 11-20 years (n=3, 4%) (72, 81, 82). In these studies there was a significant loss of participants to follow-up in the later years for large samples (39, 67, 74) or analyses were informed by a small sample from a single study centre (50). Modelling studies that generated cost-effectiveness or cost-utility metrics (n=25, 33%) (10, 20-22, 24, 26, 40, 47, 52, 54-56, 59, 76, 84-86, 89, 90, 92, 99, 101-104) generally extrapolated data from 2 to 5 years to longer term or lifetime (21, 24, 26, 40, 59, 86, 93, 101, 102), 10 years (107, 109), or <10 years (90) (Table 2).

Study design and study population

Just under half of the included studies adopted a retrospective, observational study design (n=35, 45%) (39, 41, 43-46, 48, 50, 52, 53, 57, 58, 60, 62, 64-72, 74, 75, 87, 88, 94-98, 105, 106) and 34% of these studies originated from the United States. Cohort matching techniques included studies that matched the surgical cohort with a control by adopting rigorous propensity score matching methodologies (64, 70, 74, 110) or other methodologies by matching particular variables such as comorbidity (most commonly T2DM and cardiovascular), and/or age and gender (71). Two health economics studies were particularly embedded within a randomised control trial (RCT) (85, 86). Nested cohorts from the Swedish Obese Subjects study investigated costs of in-patient care (111), sick leave and disability pension (77, 81), medication costs (112), and healthcare costs for patients with differing baseline glucose status (78). Just over one third of studies utilised modelling techniques to facilitate a full economic evaluation of the intervention (n=29, 38%) (2, 10, 20-22, 24, 26, 40, 47, 54-56, 59, 61, 63, 76, 83, 84, 86, 89, 90, 92, 93, 99, 101, 102, 104, 107, 109). Some collected economic data prospectively (42) (Table 2).

The target population was generally the severe and/or morbidly obese (26, 52) middle-aged females (47, 59, 60, 106). Studies that specifically targeted an obese male cohort included Veterans Administration studies (41, 57, 69, 70) and this study population was generally clinically more unwell with an additional or more severe comorbidity load than a corresponding female cohort (41, 70). In contrast, other studies focused on a healthier cohort with no or limited comorbidities (40, 106). Health economic metrics for people with T2DM (24, 43, 55, 56, 58, 62, 66, 67, 78, 85, 86, 90, 92, 93, 99, 101, 106, 109) were investigated and recent studies stratified this subgroup further into established versus newly diagnosed people

with diabetes (56, 85) (Table 2, Table 3A). Another recent study stratified patient groups according to baseline glucose status (euglycaemia, prediabetes and diabetes) (78). A subgroup that also emerged as an important target population was severely obese adolescents, however, only two studies met the eligibility criteria albeit with limited data (76, 84). Particular ethnic groups were also reported including Native Hawaiians (73) and South Koreans (or a predominantly Asian population) (104, 113).

Data sources

Data sources included single site administrative data (hospital administrative data and medical records) (71, 94), large private insurance claims data or health plan data (58, 59, 74), data linkage of government (tax-funded) insurance schemes (88), national surveys (56, 68), cost diaries (103), direct contact with physicians or primary care providers to augment administrative data (95), questionnaires (91), peer-reviewed journal articles (92), technical reports (90) and RCT data (85). Many included studies sourced retrospective, longitudinal data from large administrative databases (22, 52, 53, 57, 58, 64, 70, 74, 97) and/or from a single hospital site (55, 69, 94, 106). Studies from the United States analysed retrospective administrative data from either a single tertiary site or a large private insurance plan (58, 64, 67). Two recent studies from the United States explicitly used a comparison sample that was not restricted to the morbid obesity (MO) diagnosis code (70, 72). (Table 2).

Economic evaluation

Included studies reported the results of 87 partial or full economic evaluations including cost and cost analysis (n=41, 53%) (39, 41-46, 48-51, 53, 57, 58, 60, 67, 69-71, 73-75, 77-82, 87,

88, 91, 92, 94-98, 100, 102, 105, 106) cost-effectiveness analysis (n=12, 16%) (10, 20, 26, 40, 55, 84-86, 90, 99, 103), cost-utility analysis (n=23, 29%) (10, 21, 22, 24, 26, 40, 47, 54-56, 59, 76, 84, 86, 89, 90, 93, 99, 101-104, 109), cost-benefit analysis (n=3, 4%) (2, 61, 63) and return on investment (n=8, 10%) (52, 61, 62, 64-66, 68, 72). We found a cost-utility study misclassified as a cost-effectiveness study (40) and a cost analysis which claimed that bariatric surgery could be cost-effective when effectiveness measures were not included in the analysis (94).

Studies classified as partial economic evaluations reported health economics metrics such as cost per pound of weight loss (39), changes in preoperative and postoperative mean and/or median healthcare costs (including inpatient, laboratory tests, specialist visits, operating theatre, outpatient follow-up, medications) (58, 71) at particular time horizons (such as preoperative, postoperative monthly, six monthly, and 12 monthly), changes in comorbidity related medical expenses including medications (42, 45, 50, 53, 69, 82, 88) (prescribed and over-the-counter) and equipment (CPAP machinery (43)). Studies classified as full economic evaluations reported metrics such as cost per quality-adjusted life-year (47, 101), cost per life-year saved (86), cost per disability-adjusted life year (84), cost per T2DM free year (99), cost per case of T2DM remitted (85), time to breakeven (2) or net benefit (2) (Table 2 and Tables 3A and 3B).

The first included study to conduct a full economic evaluation of bariatric surgery was published in 1999 and this study was underpinned by clinical and cost data from 21 participants (102). The first widely-cited robust study to conduct a full economic evaluation of treatment versus no treatment for bariatric surgery was published in 2002 (40). This study

adopted a deterministic decision model to compare the lifetime expected costs and outcomes between gastric bypass and no treatment of severe obesity from the payer perspective.

Modeling studies were more prevalent since 2008 and modeling methodologies ranged from simple and complex decision tree/s (47, 99, 102), Markov models with memory or no memory (24, 55, 56, 84, 86), simulation models (2, 59, 107) and a combination of these approaches (104, 109). These studies investigated the cost-effectiveness of different types of bariatric surgery compared with no surgery (do nothing (89)), standard care (e.g. T2DM) (86)), and medical management (e.g. intensive supervised very low calorie diet regime (39)) (Table 2, Table 3A and 3B).

Reporting of study perspective

The perspective adopted was reported in 62 % (n=48) (2, 10, 20, 21, 24, 26, 40, 41, 47-49, 52, 54, 55, 57, 59-64, 66, 67, 69-71, 73, 76, 83-86, 88-90, 92, 93, 98, 99, 101-107, 109) of studies. Of these studies, only 13 % (n=10) (2, 20, 47, 61, 63, 84, 89, 101-103) reported employing a societal perspective. A healthcare system/thirdparty payer perspective was reported for 53% (n=41) (2, 10, 21, 22, 24, 26, 40, 41, 48, 49, 52, 54, 55, 57, 59-62, 64, 66, 67, 69-71, 73, 76, 83, 85, 86, 88-90, 92, 93, 98, 99, 104-106, 109) with three studies reporting more than one perspective (2, 61, 89). Studies that did not explicitly report a perspective (n=29, 39 %) (39, 42-46, 50, 51, 53, 56, 58, 65, 68, 72, 74, 75, 77-82, 87, 91, 94-97, 100) generally adopted a healthcare system or third party payer perspective (Table 2).

Reporting of clinical effectiveness

Effectiveness measures included health state utility values (22), percentage change in excess weight loss (103), change in BMI (60), percentage change in weight, medication consumption for comorbidities such as hypertension and diabetes mellitus (87), use of specialised equipment for sleep apnoea, systolic and diastolic blood pressure, and biochemical measures such as HbA1c and lipids (92). Cost-effectiveness and cost-utility studies all reported effectiveness measures. Some partial economic evaluations also reported effectiveness measures separately (53, 69) (Table 2).

Reporting of costs

Reporting of costs for bariatric surgery was considerably heterogeneous. Levels of precision in the identification, measurement and valuation of costs ranged from micro or unit costing (92), average per diem costs (94, 111), seeking an expert opinion from surgeons/physicians/primary care providers (104, 109) or a combination of these approaches (90, 104). Sample sizes ranged from 21 participants to over 29,000 participants at baseline and at least one study concluded that a “small sample size” precluded definitive findings (49) (Table 2).

Healthcare resource/sector costs only (including hospital and primary care) were reported in just over three-quarters (77% (n=58)) (10, 21, 22, 24, 26, 39-42, 44-46, 48-50, 52-58, 60, 62, 64, 66, 67, 69-74, 76, 78-80, 82, 83, 85-88, 90, 92-99, 104-107, 109) of the included studies and were generally limited to inpatient (including readmissions) and shorter term outpatient costs (39, 47, 66, 79, 94, 97). Many studies reported changes in mean hospital costs (e.g.

hospital care, hospital bed days, intensive care unit, nursing, medications and operating theatre) (41, 57, 79, 111). Two studies investigated changes in median costs (58, 67).

Studies that investigated changes in medication costs only (n=11, 14 %) (42-45, 50, 69, 73, 80, 82, 87, 88) were commonly sub-stratified into obesity-related comorbidities such as diabetes mellitus, cardiovascular disease, sleep apnoea and gastroesophageal reflux (42, 43, 88). One study investigated changes in prescription medication costs for LGBP patients and considered a total of 81 unique medications used to treat 21 different medical conditions (42). Another study investigated changes in medication use for an older cohort (>60 years) (87). One study considered Native Hawaiians' prescription medication costs after LRYGBP (73).

More specifically, two studies that reported average monthly medication costs for a two year time horizon found a decrease in costs of 69% for diabetes medications (both studies) and a decrease in costs for cardio-vascular medications by 31% and 43% (80, 114). A recent study found that over a one year time horizon the annual costs of medications to treat diabetes were reduced by 88% and hypertension medication costs were reduced by 65% (69). Interestingly, the same study investigated a subset of patients with persistent hypertension and/or diabetes and subsequently found a decrease in costs of 69% in diabetes medications and 58% for anti-hypertensives. Another study that investigated medication costs over a four year time horizon (2006 – 2009) for the entire Australian population that underwent LAGB surgery (n=6040) found that the greatest absolute cost reductions in year two after LAGB were observed in medications to treat diabetes (47% reduction) and cardiovascular disease (17% reduction) (88). In contrast, a recent Australian study that reported on the medication usage for an older cohort (> 60 years) found that there was not a significant average medication reduction for obesity-

related comorbidities over the time of the study (2 years) (87). Another study concluded that surgical obesity treatment lowers diabetes mellitus and cardiovascular medication costs but increases other medication costs (such as gastrointestinal tract disorder, anaemias and vitamin deficiency medications), resulting in similar total costs for surgically and conventionally treated obese individuals for 6 years (80).

Patient and family costs and other sector costs were reported in a minority of studies (n=19, 25%) (2, 20, 47, 51, 59, 61, 63, 65, 68, 75, 77, 81, 84, 89, 91, 100-103). These costs comprised out-of-pocket costs to the individual (ranging from self-pay for the primary procedure (48), travel time (89) to incidental out-of-pocket costs (115)) and costs to family members (such as direct care giving(103) or travel time) and were largely ignored. Similarly, there was a dearth of information on other sectors. However, a few studies investigated work productivity/participation (63, 100, 103), absenteeism, presenteeism (68) and pension status as a proxy for work productivity (51, 77, 81, 91). To illustrate, a recent United States based study estimated the time to breakeven and 5 year net costs of LAGB taking both medical costs and costs arising because of absenteeism and presenteeism (productivity impacts) into account. The study found that by including productivity impacts, the time to breakeven was reduced by 6 months. After 5 years, the inclusion of absenteeism and presenteeism increased savings by USD 4,780. Another study examined the cost-effectiveness of providing LAGB surgery to all morbidly obese adults in 2003 for the Australian population. The study incorporated conservative estimates of time for travel and travel costs where patients' time only was valued at 25% of the hourly wage rate and calculated based on the proportion of the Australian population employed, unemployed, or not in the workforce. The study found that when LAGB

surgery was extended to all Australians with BMI > 35 kg/m², the mean ICER becomes \$2,154/DALY averted. However, when time and travel costs for procedures and consultations were included for people BMI > 35 kg/m² the change was \$4,102/DALY averted (\$417 - \$8,720).

The cost(s) of waiting for surgery (wait-listed patients in the public sector) was not considered in 76 studies (24). A recent study claimed to be the first to attempt to quantify the potential impact of extensive waiting lists on both health costs and clinical outcomes (24). The study analysed the consequences of a three year delay in providing bariatric surgery and revealed that the overall lifetime cost in the surgical arm may be slightly reduced in non-diabetic patients with moderate and severe obesity (BMI < 40 kg/m²), but the cost was increased in non-diabetic patients with morbid or super-obesity, and people with diabetes (increase from €23 to €2,803).

Comprehensive assessment of costs encompassing sector, as incurred by the health system and patient and family and other sectors were reported in only 18% (n=14) (2, 20, 47, 59, 61, 63, 65, 68, 75, 84, 89, 101-103) of included studies. One of these studies found that the total social value for bariatric surgery was large for treated patients with incremental total social cost-effectiveness ratios typically under \$10,000 (USD) per life-year saved. The study found that the net social effect was large once improvements in life expectancy are taken into account (20).

Reporting of costs of complications and reoperations, and body contouring surgery

The consideration of reoperations and complications following the primary procedure were not included in one third of studies (n=25, 33%) (2, 21, 39, 43, 44, 50, 51, 53, 58, 62, 63, 66, 67, 69, 73, 75, 76, 80, 81, 88, 91, 106, 107). Moreover, many studies which included complications and/or reoperations adopted a relatively short timeframe or assumed a probability of the event occurring as low. One study particularly investigated the requirement for intensive care support (and associated costs) either electively or emergently for primary (210 patients) or revisional (31 patients) procedures (116). Development of complications significantly affected the hospital cost, for example, the development of deep vein thrombosis or pulmonary embolism increased the cost from mean (SD) USD 29,290 ± 55,000 to 93,000 ± 77,700. This also study found that approximately 40% of patients that required ICU admission/s were men.

The available evidence regarding the cost of complications (including early and late, minor and major) was inconsistent. Nevertheless, some of the included studies in our review provided estimates of these costs. Two studies that robustly quantified the costs of complications and reoperations over the short, medium and longer terms established that these ongoing costs could be higher than the cost of the initial procedure (26, 74). The cost of the primary procedure ranged from \$7,042 (2011 USD) for LAGB in South Korea, to \$11,290 (2003 AUD) in Australia, to \$26,315 (2011 USD) as an average cost for all procedures (Table 3B). A full economic evaluation that estimated costs for early, late, minor and major reoperations and complications estimated a range of \$426 to \$41,708, with a cost of a late moderate reoperation for LAGB \$11,115 (probability 4.9%) and LRYGBP \$14,328 (probability 8.6%) (2006 USD) (26). Similarly, a recent partial economic evaluation explored 6 year follow-up costs in surgery

patients with a control group based on inpatient admissions (by DRG) recorded in a large United States insurance administrative database. The study showed that the surgical group had significantly more admissions for digestive-related diagnoses in all 6 post-operative periods (annually for 6 years) relative to the comparison group. The study assumed that a significant proportion of these admissions were likely follow-up procedures for bariatric surgery-related complications. The mean (SD) quantified costs for the surgical group's inpatient costs years 1 to 6 (USD 2005) were year 1: \$4,193 (15,512), year 2: \$5,186 (15,935), year 3: \$4,666 (16,045), year 4: \$4,171 (15,766), year 5: \$4,302 (16,979), year 6: \$4,407 (23,166). Clearly, these costs are substantial and approach the cost of the initial procedure. In contrast, a recent cost-effectiveness analysis assumed that the cost of bariatric surgery without complications was €4,915 (range: 3,932 – 5,898) and the cost of bariatric surgery with complications was €5,766 (4,613 – 6,919) (2012 EURO).

Body contouring surgery/barioplasty costs (117, 118) were only included in 14% (n=11) (24, 40, 41, 54, 56, 59, 79, 83, 92, 100, 109) of studies and these costs were substantially underestimated in these studies by limiting costs to abdominoplasty or panniculectomy (24, 40, 41, 54, 56, 83, 92, 100, 109).

Health-related quality-of-life and health state utility values

Cost-utility studies adopted health state utility values from multi-attribute utility instruments such as the EQ-5D (59), SF 12 or 36 (119), and 15D (25). The EQ-5D dominated the valuation of health state utility values in these studies (120) (Table 2). Validated bariatric (such as the Bariatric Quality of Life (121)) or gastrointestinal specific health-related quality of life

instruments (such as the Gastrointestinal Quality of Life Index (122)) were generally not adopted, however, a recent cost-effectiveness study adopted the Bariatric Quality of Life (10).

Reporting of cost-effectiveness

Cost-effectiveness and cost-utility studies (from 2009) that investigated people with diabetes (Table 3A), found that bariatric surgery was cost-effective and in some cases cost-saving for the severely obese with T2DM (55, 56, 85, 86, 93, 99). All of these studies were undertaken from the health payer perspective, across differing time horizons and their results were robust to changes in parameter assumptions. One study found that testing of model values and assumptions either maintained the dominant status of surgical therapy or shifted the economic status of surgical therapy from dominant to cost-effective (\$13,400/QALY gained 2006 AUD) (86). Another recent study that stratified a T2DM study population into 16 sub-groups based on sex and BMI classifications across a lifetime time horizon found that bariatric surgery was cost-saving in all four pre-specified diabetic cohorts (moderately, severely, morbidly and super-obese) in both male and female patients. The study's sensitivity analysis also found that the most sensitive parameter of the cost variables was the annual cost of T2DM. (24).

Similarly, for the severely, morbidly and super-obese cohorts (generally classified by these studies as 35.0 – 35.9 kg/m², 40.0 – 49.9 kg/m² and ≥ 50 kg/m² respectively) bariatric surgery was cost-effective in the base-case analysis (20, 21, 26, 59, 89, 101, 104, 109, 123) (Table 3B). Three of these studies adopted a societal perspective (20, 89, 101). Incremental cost effectiveness ratios (cost/QALY gained) for cost-utility studies that reported in USD from 2010

to 2014 revealed base-case valuations of $\leq \$6,500/\text{QALY}$ gained. One study was an exception and reported $\$17,300/\text{QALY}$ gained for ORYGBP (an open procedure). These valuations still fall well below the accepted willingness to pay threshold of $\leq \text{USD } \$50,000/\text{QALY}$ (Table 4). Additionally, cost-utility studies that reported in EUROs from 2010 to 2014 found that bariatric surgery was dominant in the base-case analysis. Sensitivity analyses generally showed that these results were robust. One study found that the largest observed changes to base-case analysis occurred after excluding cost offsets and increasing the rates of maintenance and complications, nevertheless the reported incremental cost-effectiveness ratio still fell below the jurisdiction's willingness to pay threshold (89). One of these studies reported the range of complications and reoperations as early, late, minor and major (26).

Methodological quality

Health economics reporting for bariatric surgery was generally deficient when graded against the new CHEERS statement. Table 2 and Figures 2A and 2B provide the individual scores for included studies and overall quality was ranked as medium. Full economic evaluations generally rated highly against the new criteria ($n=18$) (10, 21, 22, 24, 26, 40, 54, 55, 66, 85, 86, 89, 90, 93, 103, 104, 107, 109) (particularly from 2010). Six partial economic evaluations were rated as low (five studies to 2008 and one study in 2012) (39, 41, 43, 49, 53, 83). The individual scores revealed that methodological quality has improved over time (Figure 2A and 2B). Critical appraisal of methodological quality against the CHEERS checklist items revealed that individual items of 'estimating of resources of costs', 'choice of model' and 'assumptions', 'analytical methods', and 'study parameters' were items where studies that rated low to medium generally did not rate adequately against the requirements of the individual criteria.

Author Manuscript

Discussion

This comprehensive systematic review synthesised disparate studies that investigated important health economic aspects of bariatric surgery as a treatment option for obesity. As an important advance on existing systematic reviews, our review included substantially more studies across the depth and breadth of the health economics literature than previous systematic reviews. We did not limit our review to full economic evaluations (cost-effectiveness and cost-utility studies). Despite the considerable heterogeneity of included studies and conflicting results from some individual studies for study populations such as T2DM, we found that common themes emerged. These themes included: bariatric surgery was generally considered cost-effective versus non-surgical interventions as a treatment option for people with morbid obesity; bariatric surgery was highly cost-effective and possibly cost-saving for severely obese patients with T2DM; only a limited spectrum of direct medical costs was considered in the majority of studies; disparate time horizons and cost information/data sources have been used; a wide range of methodological quality was an issue; a lack of consideration of the costs of many important longer term post-operative events like reoperations, complications and body contouring surgery; major gaps regarding the cost-effectiveness of bariatric surgery in particular target populations such as obese adolescents and men; and a paucity of information on indirect costs such as out-of-pocket expenses to patients and their families, work productivity gains and/or losses, and the impact of being waitlisted for three years on clinical and economic outcomes and the potential impact on patient prioritisation decisions coupled with the concept of affordability of bariatric surgery, and the disproportionate increase in

severe obesity where demand for bariatric surgery was continually exceeding the increase in supply.

Type 2 diabetes mellitus

A key finding of our systematic review was that bariatric surgery for the severely obese with T2DM was largely cost-effective.

Another theme that emerged was that bariatric surgery as a treatment option for newly diagnosed T2DM was more cost-effective (or cost-saving) than for those with established comorbidity (56, 78, 85, 86). A cost-effectiveness study based on RCT data made the point that their results actually under-estimated the cost-effectiveness of surgical therapy because they did not attempt to capture healthcare savings associated with the reduction of other obesity related morbidities or the improvements of quality of life associated with weight loss (85).

Contemporary debate about bariatric surgery as a treatment option for obesity is focused on the prioritisation of particular patient groups where there are demonstrated clinical and economic benefits. A recent editorial argued that the indications for bariatric surgery should be viewed in terms of individual patient benefit without anticipating that there would be cost savings to a healthcare system by offering this treatment and that bariatric surgery clearly benefits some patients (27). Patients considered for bariatric surgery should have a complication of obesity that is known to dramatically improve with weight loss surgery (27). Examples include diabetes and osteoarthritis (27). Nevertheless, we argue that policy and decision makers are increasingly asking not only whether an intervention works, but also whether it offers value for

money (124). More specifically, is the intervention cost-effective or even cost-saving. Bariatric surgery was identified as being highly cost-effective or even cost-saving for the severely obese with T2DM in the majority of studies. Bariatric surgery in early T2DM was found to be cost-saving, indicating that diversion of scarce healthcare resources should be considered for bariatric surgery for severely obese with T2DM.

Importantly, our review also highlighted the conflicting results of two recent studies that were informed by Swedish Obese Subjects study Swedish and Scandinavian clinical and cost data. The first study (24) modeled lifetime cost-utility analysis from the Swedish health payer perspective and revealed that bariatric surgery was cost-saving in all of the pre-specified diabetic cohorts (moderately, severely, morbidly and super-obese). In contrast, the second study (informed by long-term SOS data and cost data from Swedish sources) found no difference between the surgical and conventional treatment groups for patients with diabetes (78). We also explored the cost-effectiveness results for all full economic evaluations of people with T2DM from 2009-2015. All of these studies found that bariatric surgery was cost-effective for severely obese people with T2DM. Additionally, sensitivity analyses found that the results were robust to changes in model parameters.

Accordingly, we argue that health economics studies that investigate bariatric surgery as a treatment option for people with T2DM should adopt full (rather than partial) economic evaluation underpinned by longer time horizons and be undertaken from a societal perspective. Furthermore, health economics effort should focus on bariatric surgery as a treatment option for people with T2DM with a BMI 30-34.9 kg/m² (non-severely obese).

Body contouring/bariaptic surgery

Our review has identified a major gap in the health economics reporting of bariatric surgery where body contouring/bariaptic surgery is a significant longer term cost for many patients who experience massive weight loss after the intervention. This emerging and additional burden to the individual and/or society was not appropriately captured in the health economics reporting.

Patients requiring body contouring surgery after bariatric surgery have been described as a new and unique population that is difficult to manage, with 96% of post-bariatric surgery patients developing multiple redundant skin flaps (125). An unfortunate consequence of massive weight loss is the persistence of large quantities of excess and often inelastic skin and subcutaneous tissue. These produce a hindrance to mobility, poor cosmesis, difficulties with wound healing, intertriginous dermatitis, compromised hygiene and potentially worsened overall patient body-image despite weight loss (126). Body contouring surgery that includes, but is not limited to, panniculectomy, (circumferential) abdominoplasty, breast reduction or lift, brachioplasty, and thigh lift, serves to remove this excess tissue that remains after massive weight loss. Following body-contouring surgery, significant improvements in self-image and quality of life, as well as hygiene, mobility, and overall daily functioning have been reported (126).

Our review found that only 14% of included studies considered the costs of body contouring/bariaptic surgery in their analyses. Body contouring surgery as a follow-up procedure was first identified in this review's included studies over a decade ago. A 2002 study investigated the costs of in-patient care over 7 years among surgically and conventionally treated obese patients and concluded that a substantial fraction of the total hospital cost for

surgical treatment of obesity emerged during the years after surgery (79). Complications and sequelae of bariatric surgery cause some of these costs, but a substantial share is because of secondary plastic surgery (79). A recent study from the United Kingdom which reviewed funding models and access for barioplastic surgery highlighted that there was very little in the literature on the prevalence of barioplastic surgery after bariatric surgery (117). The only available and recent evidence based on a survey of 100 patients who had completed post-bariatric body contouring surgery in the Spanish public health system found that the cost of post-bariatric surgery body contouring treatment in a public health system unit was €8,264 (1.66 operations per patient) and that severe complications increase the average cost per patient 2.96 times (125). Importantly, the study indicated that it provided conservative estimates (public health system costs) and the rate of complications was high (up to 50%), and that although the more severe complications are rare, these represent high costs (mean €24,463). Surveyed patients also undervalued the surgery's total costs (by 17.58% or €2,034). These costs are substantially higher than cost estimates currently included in cost-effectiveness and/or cost-utility studies that provided estimates based on abdominoplasty only (e.g. €2,604) (24).

Additionally, an enormous disparity exists between the number of people who desire a body contouring surgery and those who actually received it. Two recent studies noted that a majority of post-bariatric surgery patients desire body contouring surgery, particularly in certain body areas such as waist/abdomen, upper arms, and chest/breast. Financial resources and coverage from third-party payers may be an underlying cause for the discrepancy (118, 127). From the literature it was ascertained that bariatric surgery patients will opt to pay for body contouring surgery years after the initial procedure. Although many persons who have had a bariatric

procedure will elect to have excess skin removed at a later date (at their own cost) after reaching a targeted weight, one study found that no such procedures occurred during the 2-year study period (49). The most recent evidence suggests that body contouring surgery is the final stage of the massive weight loss patient's journey and that the obese patient's journey is not complete until redundant tissue is removed (128). This study also found that around 70% of massive weight loss patients are left with redundant folds of tissue that impact on their quality of life and that these folds are heavy and cumbersome, and present functional and aesthetic problems. The surgical interventions to address these issues are much more complex than abdominoplasty and include procedures such as total body lift, upper or lower body lift, brachial lift, contouring of the trunk, and medial thigh lift. (128).

Our review recommends that the longer term costs of massive weight loss (quality of life issues regarding redundant skin flaps and/or a desire for body contouring surgery) and the actual cost of body contouring surgery (generally at the patient's own cost) should be properly considered in full economic evaluations of bariatric surgery.

Waiting for surgery and the relationship to patient prioritisation

Our review found that of 77 included studies, only one study investigated the impact of time delay on the clinical and economic outcomes of bariatric surgery. This is a key knowledge gap in the health economic reporting of bariatric surgery and is inextricably linked to the policy concept of patient prioritisation for bariatric surgery. Recent scholarly literature found that public sector waiting times are years in duration in some countries and that there are physical

(worsening of comorbidities and further weight gain) and psychosocial impacts for patients waiting for bariatric surgery (129, 130).

Constrained public sector budgets are one part of a tremendously complex system-wide healthcare landscape that results in severely and super-obese bariatric surgery candidates (with significant obesity-related comorbidities) experiencing multiyear wait times. A key reason for these multiyear wait times is the disproportionate rate of increase in severe obesity. To illustrate, a recent study identified that the National Health Service provision of bariatric surgery in the United Kingdom is “dwarfed by the rising tide of morbid obesity” (131). The study found that the number of National Health Service operations has “soared” with a rise of over 300% from 2006-07 to 2010-11. Similarly, a recent Canadian study found that severe obesity has increased in prevalence by 400% over 2 decades and is rising at a disproportionately faster rate than obesity. Additionally, the study indicated that to try and meet this increased demand, the number of publicly funded bariatric surgeries in Canada has increased 12-fold over 2 decades and that despite this trend, demand for surgery greatly exceeds supply (132). The experience in the United Kingdom and Canada suggests that governments are increasingly funding bariatric surgery as a treatment option for people who meet clinical guidelines but that the increased demand for surgery is exceeding the increase in supply. It seems likely that funders’ perceptions of “affordability” are changing as bariatric surgery has increasingly become accepted as more than a cosmetic procedure, and as the scale of the epidemic of severe obesity has become clearer.

As mentioned previously, a recent critique suggested that the indications for bariatric surgery should be viewed in terms of the individual patient benefit without anticipating that there will

be cost savings to a healthcare system by offering this treatment. Nevertheless, further studies of affordability of bariatric surgery are warranted. Additionally, full economic evaluation of bariatric surgery as a treatment option could particularly investigate subgroups of patients that are languishing on public sector waiting lists for bariatric surgery such as patients with T2DM, CVD and/or severely or super-obese.

Inclusion of complications and reoperations

Our review found that one-third of the included studies either ignored the costs and/or consequences of complications and reoperations. Studies that accounted for reoperations and complications generally only account for short term events, consider an incomplete list of complications, or assume relatively low probabilities of any of these the adverse events occurring. Additionally, many studies do not assume weight regain as an adverse event. Longer term costs of bariatric surgery have therefore probably been underestimated, and the value for money for bariatric surgery subsequently over-estimated.

A recent systematic review and meta-analysis concluded that overall complication rates associated with bariatric surgery range from 10% to 17% and reoperation rates approximately 7% (133). Other studies claim that these complication rates are much higher (up to 33 per cent), and that the rates of longer term complications are largely unknown (134). A recent study that explored the rates of complications and “what a general surgeon needs to know” suggested that band erosion can occur early or years after surgery and in some series the reported incidence rate is up to 33% (134). Another recent study on the costs of the major

complications of leaks and bleeding following sleeve gastrectomy found that median additional costs for leaks were €9284 (range €1748–125,684) and €4267 (range €1524–40,022) for bleeding (2014 EURO) (136).

Clearly, complications and reoperations after the primary procedure are not uncommon and the ongoing costs are potentially substantial. This is not appropriately reflected in many health economics analyses to date. Nevertheless, it is recognised that the issue of underreporting of complications and reoperations is a multidisciplinary problem. A recent Cochrane Review concluded that assessing the risks of different bariatric procedures is still hampered by a lack of consistency and quality of evidence in the reporting of adverse outcomes and reoperation rates, and that most studies followed participants for only one or two years; therefore the long-term effects of surgery remain unclear (135).

The Cochrane review suggested that a core set of important adverse outcomes should be identified so that a standardised approach to reporting adverse outcomes can be developed (135). Recently released standardised outcomes reporting clinical guidelines for metabolic and bariatric surgery partially addressed these issues from a clinical perspective (137). We recommend that a consistent approach should also be adopted in all health economics reporting of bariatric surgery to ensure that relevant events are appropriately and consistently accounted for.

Health economics perspective, and reported costs and cost-effectiveness

A key finding of our review was that few studies were informed by the societal perspective. The actual resources included and unit costs employed in an analysis depend on its perspective (138). In taking a societal perspective, one seeks to count all costs and benefits of medical interventions regardless of to whom they accrue (139). In turn, the adoption of a narrow perspective in most health economics reporting of bariatric surgery with inpatients costs and/or a subset of outpatients costs such as clinic follow-up or laboratory testing only included directly translates to significant costs/cost offsets not being considered. Specifically, there is a paucity of identified out-of-pocket costs, costs to family members and other sectors (such as work force participation/productivity, absenteeism and presenteeism). Our review's included studies that employed a societal perspective were informed by a limited spectrum of these societal costs and/or benefits (such as productivity impacts or time-related costs) nevertheless these studies found that the inclusion of these costs/cost offsets impacted on the results of the study.

Further, a recent health economics study argues that ignoring important costs and benefits in an economic evaluation will lead to an inefficient allocation of resources, in the short-term as well as the long-term perspective (140). Another study makes the fundamental point that the economic burden of obesity is such that society incurs substantial indirect costs including years of disability, increased mortality before retirement, early retirement, disability pensions, and work absenteeism or reduced productivity. The study also suggests that the monetary value of lost productivity is several times larger than medical costs (141). Thus there is limited information available to policy makers and/or funders within public health systems to make

fully informed decisions from a broader societal perspective as is appropriate given the wide-ranging impacts of obesity on society.

Another key finding of our review is that reported costs were very heterogeneous because the included studies' cost structures were largely informed by differing health economics perspective, time horizon and information sources. Similarly, there is a major knowledge gap in the assessment of costs of waiting for surgery. This narrow focus could be partly attributed to available data. Many studies relied on retrospective observational data from either large administrative databases such as healthcare plans or insurance data or single site administrative data such as hospital data. Measurement and valuation of identified costs also varies significantly across studies. To illustrate, some studies adopt broad average costs, other studies micro cost each input (for example each laboratory test and surgeons' time in the operating theatre). Costs are valued in different years and currencies and over different time horizons. Many studies inflate or deflate cost valuations to a base year, but some studies do not.

The way in which available resources are allocated against competing priorities is crucial in affecting how much health is generated overall, and who receives healthcare interventions and who goes without. Cost-effectiveness analysis is a tool that can assist policy makers with resource allocation (142). Nevertheless, caution needs to be exercised when comparing results of cost-effectiveness studies given variation in methodology such as perspective, time horizon, HRQoL instruments employed and the discount rates used (109). We compared cost-effectiveness results with common outcomes and found that bariatric surgery was generally cost-effective, and reported incremental cost effectiveness ratios less than the jurisdiction's willingness to pay thresholds irrespective of variations in methodology. Sensitivity analyses

also showed that the bariatric surgery was cost-effective when varying changes in key assumptions such as BMI, age, time horizon and discount rate. Costs were also varied in sensitivity analyses however, these studies largely only included direct medical costs, while costs of complications, reoperations and body contouring surgery were either substantially understated or ignored. One study's sensitivity analyses revealed that substantial changes in cost estimates had a major effect on the ICER value.

The choice of cost-effectiveness threshold is crucial in determining the value of healthcare interventions (143). International willingness to pay thresholds vary as described in Table 4, and we acknowledge that there is ongoing debate in health economics about setting thresholds (e.g. using the World Health Organisation recommended cost-effectiveness thresholds of 1-3 GDP per capita versus cost-effectiveness thresholds reflecting opportunity costs). A recent study has suggested that rather than settling on a single threshold, it would be preferable to use multiple thresholds, ideally ones based on the available resources for the relevant decision maker and possible alternative uses of those resources. For example, decision makers in resource-poor settings would have a lower willingness to pay threshold (144).

Another key finding of our systematic review is that while many studies have addressed cost-effectiveness, no studies addressed the issue of affordability. As mentioned previously, it seems likely that funders' perceptions of "affordability" have begun to change. We recommend that full economic evaluations of bariatric surgery not only consider a jurisdiction's willingness to pay, but also consider the results within the context of affordability under constrained government budgets.

A recent systematic review that investigated the costs of obesity described the disparate cost methodologies as comparing “apples and oranges” and concludes that decision makers need to be aware of the different purposes and weaknesses of studies when interpreting cost outcomes (145). Our review on the health economics reporting of bariatric surgery found considerable heterogeneity in reporting of costs for bariatric surgery. We therefore recommend thorough investigation and reporting of costs against a standardised framework such as the CHEERS checklist. We also recommend robust full economic analyses underpinned by a broad societal perspective and long term time horizon.

Methodological quality

With the increasing number of publications available, transparency and clarity in reporting are important factors when reviewing the health economics literature (36). Our review identified a wide range of methodological quality of included studies. We also identified that methodological quality has improved over time. To continue the trend in improved methodological quality, we recommend that the CHEERS statement is followed in future health economics assessments of bariatric surgery in order to further improve the quality of design, analysis and reporting.

Strengths and limitations

The key strength of our study was the comprehensive analysis of a disparate range of studies that report on health economics outcomes for bariatric surgery. We have systematically categorised, summarised, synthesised and analysed 77 studies. Our study aimed to provide a

critical analysis of the key themes and evidence-gaps in the existing scholarly literature.

Heterogeneity of the literature was also a weakness, nevertheless, we did not seek to capture homogenous studies for meta-analysis to inform a further cost-effectiveness study. As an important alternative to inform the exiting literature we aimed to adopt a broader approach to our systematic review with a view to identifying common themes and key evidence-gaps across the depth and breadth of the health economics literature.

Conclusions

Our comprehensive systematic review found that health economics reporting of bariatric surgery was characterised by heterogeneous approaches. Other key findings included a deficiency in reporting of important cost factors (due to the dominance of the healthcare system/third party payer perspective, data sources and time horizons), and key complications and ongoing surgical costs (such as revisions, reversals and remedial body-contouring surgery) in many studies. Bariatric surgery in particular subgroups of patients was identified as cost-effective (and in some cases cost saving) such as severely obese and/or newly diagnosed T2DM.

Subgroups of patients that warrant further health economic investigation were identified, in particular adolescents, long-term waitlisted patients (particularly severely obese with T2DM) and severely obese men (generally a higher comorbidity load).

Therefore, we conclude that health economists investigating bariatric surgery should strive to undertake full economic evaluations that would rate at the highest levels for methodological quality against the CHEERS statement, underpinned by a societal perspective and broad life

course costs and consequences. Only through such a robust approach will accurate measures of cost-effectiveness be established, and more reliable and targeted decision-making be implemented. Further, thorough investigation of costs and consequences will drive more accurate reporting of bariatric surgery complications and reoperations (including body contouring surgery).

Evidence from economic evaluation is used in healthcare decision making if the evidence is accessible and acceptable (146). Health economics reporting of bariatric surgery as a treatment option for obesity should serve to enhance clinical appraisal with robust and accessible health economic evidence. It is incumbent on the health economics community to educate decision and policy makers (who allocate scarce healthcare resources) about the different strengths and weaknesses of health economics reporting for bariatric surgery, and to ensure that decisions are based upon the best quality and most relevant evidence available.

Contemporary debate about bariatric surgery as a treatment option for obesity is focused on the prioritisation of particular patient groups for whom there are demonstrated clinical and economic benefits. There is also emerging debate on the impact of waiting times on patients' physical and psychosocial health, and their associated costs. The heterogeneity of the literature notwithstanding, on the basis of this review there are clear signals to support the allocation of scarce resources to particular patients groups such as severely obese with T2DM. Health economists should also endeavour to investigate particular patient groups through robust full economic evaluation in order to provide more and better evidence in subgroups such as non-severely obese with T2DM, severely obese adolescents that are emerging as potentially cost-

saving from a longer term societal perspective, and patients waiting long periods on public waiting lists for bariatric surgery.

Compliance with ethical standards

Disclosure of potential conflicts of interest: This work was supported by a National Health and Medical Research Council (NHMRC) Partnership Project Grant (APP1076899).

Author Manuscript

References

1. Finkelstein EA, Ruhm CJ, Kosa KM. Economic causes and consequences of obesity. *Annu Rev Public Health*. 2005; **26**: 239-57.
2. Finkelstein EA, Brown DS. A cost-benefit simulation model of coverage for bariatric surgery among full-time employees. *Am J Manag Care*. 2005; **11(10)**: 641-63.
3. Bhattacharya J, Sood N. Who pays for obesity? *J of Econ Perspect*. 2011; **25(1)**: 139-58.
4. Temple Newhook J, Gregory D, Twells L. The road to “severe obesity”: weight loss surgery candidates talk about their histories of weight gain. *J Soc Behav Health Sci*. 2013; **7(1)**: 35-51.
5. World Health Organization (2015) Obesity and Overweight Factsheet No. 311.
6. Organization for Economic Co-operation and Development (OECD) (2013): *OECD Factbook 2013: Economic, Environmental and Social Statistics*. OECD Publishing: Paris, 2013.
7. Kral JG, Kava RA, Catalano PM, Moore BJ. Severe obesity: The neglected epidemic. *Obes Facts*. 2012; **5(2)**: 254-69.
8. Cawley J, Meyerhoefer C. The medical care costs of obesity: an instrumental variables approach. *J Health Econ*. 2012; **31(1)**: 219-30.
9. Gould JC. What's in a name? *Arch Surg*. 2011; **146(6)**: 750-1.
10. Chang SH, Stoll CR, Colditz GA. Cost-effectiveness of bariatric surgery: should it be universally available? *Maturitas*. 2011; **69(3)**: 230-8.
11. Buchwald H, Oien DM. Metabolic/bariatric surgery worldwide 2011. *Obes Surg*. 2013; **23(4)**: 427-36.
12. Buchwald H, Oien DM. Metabolic/bariatric surgery worldwide 2008. *Obes Surg*. 2009; **19(12)**: 1605-11.
13. Angrisani L, Santonicola A, Iovino P, Formisano G, Buchwald H, Scopinaro N. Bariatric Surgery Worldwide 2013. *Obes Surg*. 2015; **25(10)**: 1822-32.
14. Gloy VL, Briel M, Bhatt D, et al. Bariatric surgery versus non-surgical treatment for obesity: A systematic review and meta-analysis of randomized controlled trials. *BMJ*. 2013; Oct 22;347:f5934.
15. Colquitt JL, Picot J, Loveman E, Clegg AJ. Surgery for obesity. *Cochrane Database Syst Rev*. 2009 Apr 15; (2) CD003641.
16. Jones ND. Surgery for obesity: No funding for NICE treatment. *BMJ*. 2009; **339(7726)**: 877.
17. Henderson J. *Health Economics and Policy (with Economic Applications)*. 5th Edition. South-western Cengage Learning. Mason, Ohio, 2011.
18. Drummond MF, Sculpher M, Torrance G, O'Brien B, Stoddart G. *Methods for the economic evaluation of health care programmes*. 3rd Edition. Oxford University Press. New York, 2005.
19. Shemilt I, Mugford M, Drummond M, et al. Economics methods in Cochrane systematic reviews of health promotion and public health related interventions. *BMC Med Res Methodol*. 2006; **6(1)**: 55.
20. Michaud PC, Goldman DP, Lakdawalla DN, Zheng Y, Gailey AH. The value of medical and pharmaceutical interventions for reducing obesity. *J Health Econ*. 2012; **31(4)**: 630-43.

21. Castilla I, Mar J, Valcarcel-Nazco C, Arrospide A, Ramos-Goni JM. Cost-utility analysis of gastric bypass for severely obese patients in Spain. *Obes Surg*. 2014; **24**(12): 2061-8.
22. Wang BC, Wong ES, Alfonso-Cristancho R, et al. Cost-effectiveness of bariatric surgical procedures for the treatment of severe obesity. *Eur J Health Econ*. 2014; **15**(3): 253-63.
23. Anselmino M, Bammer T, Fernández Cebrián JM, Daoud F, Romagnoli G, Torres A. Cost-effectiveness and budget impact of obesity surgery in patients with type 2 diabetes in Three European countries(II). *Obes Surg*. 2009; **19**(11): 1542-9.
24. Borisenko O, Adam D, Funch-Jensen P, et al. Bariatric surgery can lead to net cost savings to health care systems: results from a comprehensive european decision analytic model. *Obes Surg*. 2015; **25**(9): 1559-68.
25. Mäklin S, Malmivaara A, Linna M, Victorzon M, Koivukangas V, Sintonen H. Cost-utility of bariatric surgery for morbid obesity in Finland. *Br J Surg*. 2011; **98**(10): 1422-9.
26. Campbell J, McGarry LA, Shikora SA, Hale BC, Lee JT, Weinstein MC. Cost-effectiveness of laparoscopic gastric banding and bypass for morbid obesity. *Am J Manag Care*. 2010; **16**(7): e174-87.
27. Livingston EH. Is bariatric surgery worth it? *JAMA Surgery*. 2013; **148**(6): 562.
28. Anderson R. Systematic reviews of economic evaluations: utility or futility? *Health Econ*. 2010; **19**(3): 350-64.
29. Padwal R, Klarenbach S, Wiebe N, et al. Bariatric surgery: A systematic review of the clinical and economic evidence. *J Gen Intern Med*. 2011; **26**(10): 1183-94.
30. Clegg AJ, Colquitt J, Sidhu MK, Royle P, Loveman E, Walker A. The clinical effectiveness and cost-effectiveness of surgery for people with morbid obesity: a systematic review and economic evaluation. *Health Technol Assess*. 2002; **6**(12): 1-153.
31. Salem L, Jensen CC, Flum DR. Are bariatric surgical outcomes worth their cost? A systematic review. *JACS*. 2005; **200**(2): 270-8.
32. Klarenbach S, Padwal R, Wiebe N, et al *Bariatric Surgery for Severe Obesity: Systematic Review and Economic Evaluation*. Ottawa: Canadian Agency for Drugs and Technologies in Health. 2010.
33. Wang BCM, Furnback W. Modelling the long-term outcomes of bariatric surgery: A review of cost-effectiveness studies. *Best Pract Res Clin Gastroenterol*. 2013; **27**(6): 987-95.
34. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Ann Intern Med*. 2009; **151**(4): 264-9.
35. Green S. *Cochrane handbook for systematic reviews of interventions version 5.1*. The Cochrane Collaboration. 2011.
36. Husereau D, Drummond M, Petrou S, et al. Consolidated health economic evaluation reporting standards (CHEERS) statement. *BMC Med*. 2013; **11**(1): 80.
37. Shemilt I, Mugford M, Vale L, Marsh K, Donaldson C, Drummond M. Evidence synthesis, economics and public policy. *Res Synth Methods*. 2010; **1**(2): 126-35.
38. Higgins JP, Green S. *Cochrane handbook for systematic reviews of interventions*: Wiley Online Library; 2008.
39. Martin LF, Tan TL, Horn JR, Bixler EO, Kauffman GL, Becker DA, et al. Comparison of the costs associated with medical and surgical treatment of obesity. *Surgery*. 1995; **118**(4): 599-606.
40. Craig BM, Tseng DS. Cost-effectiveness of gastric bypass for severe obesity. *Am J Med*. 2002; **113**(6): 491-8.

41. Gallagher SF, Banasiak M, Gonzalvo JP, et al. The impact of bariatric surgery on the Veterans Administration healthcare system: A cost analysis. *Obes Surg.* 2003; **13**(2): 245-8.
42. Gould JC, Garren MJ, Starling JR. Laparoscopic gastric bypass results in decreased prescription medication costs within 6 months. *J Gastrointest Surg.* 2004; **8**(8): 983-7.
43. Monk JS, Jr., Dia Nagib N, Stehr W. Pharmaceutical savings after gastric bypass surgery. *Obes Surg.* 2004; **14**(1): 13-5.
44. Potteiger CE, Paragi PR, Inverso NA, et al. Bariatric surgery: Shedding the monetary weight of prescription costs in the managed care arena. *Obes Surg.* 2004; **14**(6): 725-30.
45. Snow LL, Weinstein LS, Hannon JK, et al. The effect of Roux-en-Y gastric bypass on prescription drug costs. *Obes Surg.* 2004; **14**(8): 1031-5.
46. Cendan JC, Abu-Aouf D, Gabrielli A, et al. Utilization of intensive care resources in bariatric surgery. *Obes Surg.* 2005; **15**(9): 1247-51.
47. Jensen C, Flum DR. The costs of nonsurgical and surgical weight loss interventions: is an ounce of prevention really worth a pound of cure? *Surg Obes Relat Dis.* 2005; **1**(3): 353-7.
48. Mehrotra C, Serdula M, Naimi TS, Khan LK, Miller J, Dietz W. Population-based study of trends, costs, and complications of weight loss surgeries from 1990 to 2002. *Obes Res.* 2005; **13**(11): 2029-34.
49. Gorman RS, Stern DL, Inclan DV, Presutti RJ, Swain JM, Hentz JG. Outcomes, health status, and medical resource utilization after bariatric surgery. *Compr Ther.* 2006; **32**(1): 34-8.
50. Nguyen NT, Varela JE, Sabio A, Naim J, Stamos M, Wilson SE. Reduction in prescription medication costs after laparoscopic gastric bypass. *Am Surg.* 2006; **72**(10): 853-6.
51. Wagner AJ, Fabry JM, Jr., Thirlby RC. Return to work after gastric bypass in Medicaid-funded morbidly obese patients. *Arch Surg.* 2007; **142**(10): 935-40.
52. Cremieux PY, Buchwald H, Shikora SA, Ghosh A, Yang HE, Buessing M. A study on the economic impact of bariatric surgery. *Am J Manag Care.* 2008; **14**(9): 589-96.
53. Hodo DM, Waller JL, Martindale RG, Fick DM. Medication use after bariatric surgery in a managed care cohort. *Surg Obes Relat Dis.* 2008; **4**(5): 601-7.
54. Salem L, Devlin A, Sullivan SD, Flum DR. Cost-effectiveness analysis of laparoscopic gastric bypass, adjustable gastric banding, and nonoperative weight loss interventions. *Surg Obes Relat Dis.* 2008; **4**(1): 26-32.
55. Ikramuddin S, Klingman CD, Swan T, Minshall ME. Cost-effectiveness of Roux-en-Y gastric bypass in type 2 diabetes patients. *Am J Manag Care.* 2009; **15**(9): 607-15.
56. Hoerger TJ, Zhang P, Segel JE, Kahn HS, Barker LE, Couper S. Cost-effectiveness of bariatric surgery for severely obese adults with diabetes. *Diabetes Care.* 2010; **33**(9): 1933-9.
57. Maclejewski ML, Smith VA, Livingston EH, et al. Health care utilization and expenditure changes associated with bariatric surgery. *Med Care.* 2010; **48**(11): 989-98.
58. Makary MA, Clark JM, Shore AD, et al. Medication utilization and annual health care costs in patients with type 2 diabetes mellitus before and after bariatric surgery. *Arch Surg.* 2010; **145**(8): 726-31.
59. McEwen LN, Coelho RB, Baumann LM, Bilik D, Nota-Kirby B, Herman WH. The cost, quality of life impact, and cost-utility of bariatric surgery in a managed care population. *Obes Surg.* 2010; **20**(7): 919-28.
60. Mullen DM, Marr TJ. Longitudinal cost experience for gastric bypass patients. *Surg Obes Relat Dis.* 2010; **6**(3): 243-8.

61. Perryman MR, Gleghorn V. Obesity-related costs and the economic impact of laparoscopic adjustable gastric banding procedures: benefits in the Texas Employees Retirement System. *J Med Econ*. 2010; **13**(2): 339-50.
62. Cremieux PY, Eapen S, Trask SW, Ghosh A. Weighing the clinical benefits and economic impact of bariatric surgery in morbidly obese patients with diabetes. *Can J Diabetes*. 2011; **35**(2): 89-98.
63. Ewing BT, Thompson MA, Wachtel MS, Frezza EE. A cost-benefit analysis of bariatric surgery on the South Plains region of Texas. *Obes Surg*. 2011; **21**(5): 644-9.
64. Finkelstein EA, Allaire BT, Burgess SM, Hale BC. Financial implications of coverage for laparoscopic adjustable gastric banding. *Surg Obes Relat Dis*. 2011; **7**(3): 295-303.
65. Finkelstein EA, Allaire BT, Dibonaventura MD, Burgess SM. Direct and indirect costs and potential cost savings of laparoscopic adjustable gastric banding among obese patients with diabetes. *J Occup Env Med*. 2011; **53**(9): 1025-9.
66. Klein S, Ghosh A, Cremieux PY, Eapen S, McGavock TJ. Economic impact of the clinical benefits of bariatric surgery in diabetes patients with BMI (greater-than or equal to)35 kg/m2. *Obesity*. 2011; **19**(3): 581-7.
67. Bleich SN, Chang HY, Lau B, et al. Impact of bariatric surgery on health care utilization and costs among patients with diabetes. *Med Care*. 2012; **50**(1): 58-65.
68. Finkelstein EA, Allaire BT, DiBonaventura MD, Burgess SM. Incorporating indirect costs into a cost-benefit analysis of laparoscopic adjustable gastric banding. *Value Health*. 2012; **15**(2): 299-304.
69. Ghiassi S, Morton J, Bellatorre N, Eisenberg D. Short-term medication cost savings for treating hypertension and diabetes after gastric bypass. *Surg Obes Relat Dis*. 2012; **8**(3): 269-74.
70. Maciejewski ML, Livingston EH, Smith VA, Kahwati LC, Henderson WG, Arterburn DE. Health expenditures among high-risk patients after gastric bypass and matched controls. *Arch Surg*. 2012; **147**(7): 633-40.
71. Myers VH, McVay MA, Adams CE, et al. Actual medical and pharmacy costs for bariatric surgery: 6-Year follow-up. *South Med J*. 2012; **105**(10): 530-7.
72. Finkelstein EA, Allaire BT, Globe D, Dixon JB. The business case for bariatric surgery revisited: a non-randomized case-control study. *PloS one*. 2013; **8**(9): e75498.
73. Lam EC, Murariu D, Takahashi E, Park CW, Bueno RS, Lorenzo CS. Prescription drug cost reduction in Native Hawaiians after laparoscopic Roux-en-y gastric bypass. *Hawai'i J Med Public Health*. 2013; **72**(2): 40-3.
74. Weiner JP, Goodwin SM, Chang HY, et al. Impact of bariatric surgery on health care costs of obese persons: A 6-year follow-up of surgical and comparison cohorts using health plan data. *JAMA Surg*. 2013; **148**(6): 555-62.
75. Warren JA, Ewing JA, Hale AL, Blackhurst DW, Bour ES, Scott JD. Cost-effectiveness of bariatric surgery: increasing the economic viability of the most effective treatment for type II diabetes mellitus. *Am Surg*. 2015; **81**(8): 807-11.
76. Bairdain S, Samnaliev M. Cost-effectiveness of adolescent bariatric surgery. *Cureus*. 2015; **7**(2): e248.
77. Narbro K, Agren G, Jonsson E, et al. Sick leave and disability pension before and after treatment for obesity: a report from the Swedish Obese Subjects (SOS) study. *Int J Obesity*. 1999; **23**(6): 619-24.

78. Keating C, Neovius M, Sjöholm K, et al. Health-care costs over 15 years after bariatric surgery for patients with different baseline glucose status: results from the Swedish Obese Subjects study. *Lancet Diabetes Endocrinol.* 2015.
79. Agren G, Narbro K, Jonsson E, Naslund I, Sjostrom L, Peltonen M. Cost of in-patient care over 7 years among surgically and conventionally treated obese patients. *Obes Res.* 2002; **10(12)**: 1276-83.
80. Narbro K, Agren G, Jonsson E, Naslund I, Sjostrom L, Peltonen M. Pharmaceutical costs in obese individuals: comparison with a randomly selected population sample and long-term changes after conventional and surgical treatment: The SOS intervention study. *Arch Intern Med.* 2002; **162(18)**: 2061-9.
81. Gripeteg L, Lindroos AK, Peltonen M, Sjostrom L, Narbro K. Effects of bariatric surgery on disability pension in Swedish obese subjects. *Int J Obesity.* 2012; **36(3)**: 356-62.
82. Neovius M, Narbro K, Keating C, et al. Health care use during 20 years following bariatric surgery. *JAMA.* 2012; **308(11)**: 1132-41.
83. Borg S, Naslund I, Persson U, Odegaard K. Budget impact analysis of surgical treatment for obesity in Sweden. *Scand J Surg.* 2012; **101(3)**: 190-7.
84. Ananthapavan J, Moodie M, Haby M, Carter R. Assessing cost-effectiveness in obesity: laparoscopic adjustable gastric banding for severely obese adolescents. *Surg Obes Relat Dis.* 2010; **6(4)**: 377-85.
85. Keating CL, Peeters A, Dixon JB, Playfair J, Moodie ML, O'Brien PE. Cost-efficacy of surgically induced weight loss for the management of type 2 diabetes. *Diabetes Care.* 2009; **32(4)**: 580-4.
86. Keating CL, Bulfone L, Dixon JB, et al. Cost-effectiveness of surgically induced weight loss for the management of type 2 diabetes: Modeled lifetime analysis. *Diabetes Care.* 2009; **32(4)**: 567-74.
87. Clough A, Layani L, Shah A, Wheatley L, Taylor C. Laparoscopic gastric banding in over 60s. *Obes Surg.* 2011; **21(1)**: 10-7.
88. Keating CL, Peeters A, Swinburn BA, Carter R, Moodie ML. Pharmaceutical utilisation and costs before and after bariatric surgery. *Int J Obesity.* 2013; **37(11)**: 1467-72.
89. Lee YY, Veerman JL, Barendregt JJ. The cost-effectiveness of laparoscopic adjustable gastric banding in the morbidly obese adult population of Australia. *PloS one.* 2013; **8(5)**: e64965.
90. Ackroyd R, Mouiel J, Chevallier JM, Daoud F. Cost-effectiveness and budget impact of obesity surgery in patients with type-2 diabetes in three European countries. *Obes Surg.* 2006; **16(11)**: 1488-503.
91. Hawkins SC, Osborne A, Finlay IG, Alagaratnam S, Edmond JR, Welbourn R. Paid work increases and state benefit claims decrease after bariatric surgery. *Obes Surg.* 2007; **17(4)**: 434-7.
92. Pollock RF, Chilcott J, Muduma G, Valentine WJ. Laparoscopic adjustable gastric banding vs standard medical management in obese patients with type 2 diabetes: a budget impact analysis in the UK. *J Med Econ.* 2013; **16(2)**: 249-59.
93. Pollock RF, Muduma G, Valentine WJ. Evaluating the cost-effectiveness of laparoscopic adjustable gastric banding versus standard medical management in obese patients with type 2 diabetes in the UK. *Diabetes, Obes Metab.* 2013; **15(2)**: 121-9.

94. Karim MA, Ahmed J, Arneil C, Ali A. Utilization of hospital services by obese patients before and after bariatric surgery. *Surg Today*. 2013; **43(10)**: 1129-33.
95. Karim MA, Clifton E, Ahmed J, Mackay GW, Ali A. Economic evaluation of bariatric surgery to combat morbid obesity: a study from the West of Scotland. *Asian J of Endosc Surg*. 2013; **6(3)**: 197-202.
96. Christou NV, Sampalis JS, Liberman M, et al. Surgery decreases long-term mortality, morbidity, and health care use in morbidly obese patients. *Ann Surg*. 2004; **240(3)**: 416-424.
97. Sampalis JS, Liberman M, Auger S, Christou NV. The impact of weight reduction surgery on health-care costs in morbidly obese patients. *Obes Surg*. 2004; **14(7)**: 939-47.
98. Czernichow S, Moszkowicz D, Szwarzensztejn K, et al. Impact of bariatric surgery on the medical management and costs of obese patients in France: an analysis of a national representative claims database. *Obes Surg*. 2015; **25(6)**: 986-96.
99. Anselmino M, Bammer T, Fernandez, et al. Cost-effectiveness and budget impact of obesity surgery in patients with type 2 diabetes in Three European countries(II). *Obes Surg*. 2009; **19(11)**: 1542-9.
100. Roger Andersen J, Aasprang A, Bergsholm P, Sletteskog N, Vage V, Karin Natvig G. Health-related quality of life and paid work participation after duodenal switch. *Obes Surg*. 2010; **20(3)**: 340-5.
101. Faria GR, Preto JR, Costa-Maia J. Gastric bypass is a cost-saving procedure: results from a comprehensive Markov model. *Obes Surg*. 2013; **23(4)**: 460-6.
102. van Gemert WG, Adang EM, Kop M, Vos G, Greve JW, Soeters PB. A prospective cost-effectiveness analysis of vertical banded gastroplasty for the treatment of morbid obesity. *Obes Surg*. 1999; **9(5)**: 484-91.
103. van Mastrigt GA, van Dielen FM, Severens JL, Voss GB, Greve JW. One-year cost-effectiveness of surgical treatment of morbid obesity: vertical banded gastroplasty versus lap-band. *Obes Surg*. 2006; **16(1)**: 75-84.
104. Song HJ, Kwon JW, Kim YJ, Oh SH, Heo Y, Han SM. Bariatric surgery for the treatment of severely obese patients in South Korea - Is it cost effective? *Obes Surg*. 2013; **23(12)**: 2058-67.
105. Kelles SM, Barreto SM, Guerra HL. Costs and usage of healthcare services before and after open bariatric surgery. *Sao Paulo Med J*. 2011; **129(5)**: 291-9.
106. Sussenbach SP, Padoin AV, Silva EN, et al. Economic benefits of bariatric surgery. *Obes Surg*. 2012; **22(2)**: 266-70.
107. Zanela OO, Cabra HA, Melendez G, Anaya P, Rupprecht F. Economic evaluation of bariatric surgery in Mexico using discrete event simulation. *Value Health Reg Issues*. 2012; **1(2)**: 172-9.
108. Buchwald H, Buchwald JN. Evolution of operative procedures for the management of morbid obesity 1950-2000. *Obes Surg*. 2002; **12(5)**: 705-17.
109. Maklin S, Malmivaara A, Linna M, Victorzon M, Koivukangas V, Sintonen H. Cost-utility of bariatric surgery for morbid obesity in Finland. *Br J Surg*. 2011; **98(10)**: 1422-9.
110. Finkelstein EA, Allaire BT, Globe D, Dixon JB. The business case for bariatric surgery revisited: a non-randomized case-control study. *PloS one*. 2013; **8(9)**: e75498.
111. Ågren G, Narbro K, Jonsson E, Näslund I, Sjöström L, Peltonen M. Cost of in-patient care over 7 years among surgically and conventionally treated obese patients. *Obes Res*. 2002; **10(12)**: 1276-83.

112. Narbro K, Ågren G, Jonsson E, Näslund I, Sjöström L, Peltonen M. Pharmaceutical costs in obese individuals: comparison with a randomly selected population sample and long-term changes after conventional and surgical treatment: the SOS intervention study. *Arch Int Med*. 2002; **162(18)**: 2061-9.
113. Heo YS, Park JM, Kim YJ, et al. Bariatric surgery versus conventional therapy in obese Korea patients: a multicenter retrospective cohort study. *J Korean Surg Soc*. 2012; **83(6)**: 335-42.
114. Nguyen NT, Varela JE, Sabio A, Naim J, Stamos M, Wilson SE. Reduction in prescription medication costs after laparoscopic gastric bypass. *Am Surg*. 2006; **72(10)**: 853-6.
115. Encinosa WE, Bernard DM, Steiner CA, Chen CC. Trends: use and costs of bariatric surgery and prescription weight-loss medications. *Health Aff*. 2005; **24(4)**: 1039-46.
116. Cendán JC, Abu-Aouf D, Gabrielli A, et al. Utilization of intensive care resources in bariatric surgery. *Obes Surg*. 2005; **15(9)**: 1247-51.
117. Agrawal S, Mukherjee S, Kamat S, Adegbola S. Bariplastic (post bariatric body-contouring) surgery in England: A 'postcode' lottery. *Obes Surg*. 2012; **22(8)**: 1153.
118. Mitchell JE, Crosby RD, Ertelt TW, et al. The desire for body contouring surgery after bariatric surgery. *Obes Surg*. 2008; **18(10)**: 1308-12.
119. Brazier J, Roberts J, Deverill M. The estimation of a preference-based measure of health from the SF-36. *J Health Econ*. 2002; **21(2)**: 271-92.
120. Campbell JA, Palmer AJ, Venn A, Sharman M, Otahal P, Neil A. A head-to-head comparison of the EQ-5D-5L and AQoL-8D multi-attribute utility instruments in patients who have previously undergone bariatric surgery. *Patient*. 2016 Feb 3:1-12 [Epub ahead of print].
121. Weiner S, Sauerland S, Weiner R, Cyzewski M, Brandt J, Neugebauer E. Validation of the adapted bariatric quality of life index (BQL) in a prospective study in 446 bariatric patients as one-factor model. *Obes Facts*. 2009; **2**: 63-6.
122. Eypasch E, Williams J, Wood-Dauphinee S, et al. Gastrointestinal quality of life index: development, validation and application of a new instrument. *Br J Surg*. 1995; **82(2)**: 216-22.
123. Wang BCM, Wong ES, Alfonso-Cristancho R, et al. Cost-effectiveness of bariatric surgical procedures for the treatment of severe obesity. *Eur J Health Econ*. 2014; **15(3)**: 253-63.
124. Gortmaker SL, Swinburn BA, Levy D, et al. Changing the future of obesity: science, policy, and action. *Lancet*. 2011; **378(9793)**: 838-47.
125. Poyatos JV, Del Castillo JMB, Sales BO, Vidal AA. Post-bariatric surgery body contouring treatment in the public health system: Cost study and perception by patients. *Plast Reconstr Surg*. 2014; **134(3)**: 448-54.
126. Reiffel AJ, Jimenez N, Burrell WA, Millet YH, Dent BL, Pomp A, et al. Body contouring after bariatric surgery: how much is really being done? *Ann Plast Surg*. 2013; **70(3)**: 350-3.
127. Kitzinger HB, Abayev S, Pittermann A, et al. After massive weight loss: patients' expectations of body contouring surgery. *Obes Surg*. 2012; **22(4)**: 544-8.
128. Soldin M, Bain CJ, Mughal M. *Body Contouring Surgery after Bariatric Surgery. Obesity, Bariatric and Metabolic Surgery*. Springer International Publishing: Switzerland. 2016. p. 713-21.
129. Gregory DM, Temple Newhook J, Twells LK. Patients' perceptions of waiting for bariatric surgery: a qualitative study. *Int J Equity Health*. 2013; Oct 18: 12:86.

130. Padwal RS, Rueda-Clausen CF, Sharma AM, et al. Weight loss and outcomes in wait-listed, medically managed, and surgically treated patients enrolled in a population-based bariatric program: prospective cohort study. *Med Care*. 2014;**52**(3): 208-15.
131. Owen-Smith A, Kipping R, Donovan J, Hine C, Maslen C, Coast J. A NICE example? Variation in provision of bariatric surgery in England. *BMJ*. 2013; 346:f2453.
132. Gill RS, Majumdar SR, Wang X, et al. Prioritization and willingness to pay for bariatric surgery: the patient perspective. *Can J Surg*. 2014; **57**(1): 33-9.
133. Chang SH, Stoll CRT, Song J, Varela JE, Eagon CJ, Colditz GA. The effectiveness and risks of bariatric surgery an updated systematic review and meta-analysis, 2003-2012. *JAMA Surg*. 2014; **149**(3): 275-87.
134. Healy P, Clarke C, Reynolds I, Arumugasamy M, McNamara D. Complications of bariatric surgery—what the general surgeon needs to know. *Surgeon*. 2016; **14**(2): 91-8.
135. Colquitt JL, Pickett K, Loveman E, Frampton GK. Surgery for weight loss in adults. *Cochrane Database Syst Rev*. 2014; **8**: CD003641.pub4.
136. Bransen J, Gilissen LP, van Rutte PW, Nienhuijs SW. Costs of leaks and bleeding after sleeve gastrectomies. *Obes Surg*. 2015; **25**(10): 1767-1771
137. Brethauer SA, Kim J, El Chaar M, et al. Standardized outcomes reporting in metabolic and bariatric surgery. *Surg Obes Relat Dis*. 2015; **11**(3): 489-506.
138. Neil AL, Carr VJ, Mihalopoulos C, Mackinnon A, Morgan VA. Costs of psychosis in 2010: findings from the second Australian National Survey of Psychosis. *Aust NZ J Psychiatry*. 2014; **48**(2): 169-82.
139. Pauly MV, Pedro PB. *Handbook of Health Economics*. Volume 2: Elsevier; 2011. p. i.
140. Jönsson B. Ten arguments for a societal perspective in the economic evaluation of medical innovations. *Eur J Health Econ*. 2009; **10**(4): 357-9.
141. Wang YC, McPherson K, Marsh T, Gortmaker SL, Brown M. Health and economic burden of the projected obesity trends in the USA and the UK. *Lancet*. 2011; **378**(9793): 815-25.
142. Woods B, Revill P, Sculpher M, Claxton KP. Country-level cost-effectiveness thresholds: initial estimates and the need for further research. York, UK: Centre for Health Economics, University of York. 2015 Mar, p. 1-24. (CHE Research Paper; 109).
143. Ryen L, Svensson M. The willingness to pay for a quality adjusted life year: a review of the empirical literature. *Health Econ*. 2015; **24**(10): 1289-301.
144. Neumann PJ, Cohen JT, Weinstein MC. Updating cost-effectiveness—the curious resilience of the \$50,000-per-QALY threshold. *New Engl J Med*. 2014; **371**(9): 796-7.
145. Bierl M, Marsh T, Webber L, Brown M, McPherson K, Rtveladze K. Apples and oranges: a comparison of costing methods for obesity. *Obes Rev*. 2013; **14**(9): 693-706.
146. Merlo G, Page K, Ratcliffe J, Halton K, Graves N. Bridging the gap: exploring the barriers to using economic evidence in healthcare decision making and strategies for improving uptake. *Appl Health Econ Health Policy*. 2014; **13**(3): 303-309.
147. The National Institute for Health and Care Excellence (NICE) (2013). Guide to the methods of technology appraisal 2013. <http://publicationsniceorguk/pmg9>
148. 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**(4): 473.

149. Giacomini M. How good is good enough? Standards in policy decisions to cover new health technologies. *Healthc Policy*. 2007; **3(2)**: 91.
150. Shiroya T, Sung YK, Fukuda T, Lang HC, Bae SC, Tsutani K. International survey on willingness-to-pay (WTP) for one additional QALY gained: what is the threshold of cost effectiveness? *Health Econ*. 2010; **19(4)**: 422-37.

Author Manuscript

Table 1: Search strategy based on PRISMA methodology:

Long Search	#1 AND #2 AND #3 NOT #4
#1 Economic filters (outcome)	"economic evaluation" OR cost OR effectiveness OR "cost effectiveness" OR "cost benefit" OR "cost analysis" OR "cost utility" OR CUA OR CBA OR CEA OR "health economic*" OR economic* OR "direct cost" OR "indirect cost" OR "intangible cost" OR "health care cost" OR " " OR "quality adjusted life year" OR QALY OR utility OR "economic benefit" OR "economic evaluation" in Title, Abstract or Keywords (outcome);
#2 Participant/ #3 Intervention	"bariatric surgery" OR "obesity surgery" OR "metabolic surgery" OR "weight loss surgery" OR "laparoscopic adjustable gastric band" OR "swedish adjustable gastric band" OR "gastric bypass" OR LAGB OR SAGB OR RYGB OR VGB OR "roux-en-Y" OR "gastric sleeve" " in Title, Abstract or Keywords (participant and intervention);
#4 Excluding	NOT "animal" in Title, Abstract or Keywords
MeSH and Emtree Search	<p>("Health Care Economics and Organizations" explode all trees [MeSH] AND "Bariatric Surgery" explode all trees [MeSH]; "Bariatric Surgery" explode all trees [MeSH] AND "Quality of Life" explode all trees [MeSH])</p> <p>("bariatric surgery" explode all trees [Emtree] AND "economic aspect" explode all trees [MeSH]; "Bariatric Surgery" explode all trees [MeSH] AND "quality of Life" explode all trees [Emtree])</p>

Table 2: Characteristics of included studies (n = 77)

Key: AUD = Australian Dollar; BIA = budget impact analysis; BPD = British Pound; CBA = cost-benefit analysis; ; CCA = cost and cost analysis; CEA = cost-effectiveness analysis; CM = comorbidity; CT = conventional treatment; CUA = cost-utility analysis; CVD = cardio-vascular disease; DM = diabetes mellitus; DR = discount rate; EURO = Euro; GB = gastric band; GBP = gastric bypass;; GERD = gastro-oesophageal reflux disease; GID = gastro-intestinal disease; GP = general practitioner; GST=gastric stapling; HLP = hyperlipidaemia; HT = hypertension; ICER = incremental cost-effectiveness ratio; LAGB = laparoscopic adjustable gastric band; LRYGBP = laparoscopic Roux-en-Y gastric bypass; LSG = laparoscopic sleeve gastrectomy; LY = life years; Meds = medications; MO = morbid obesity code; NHP I and II = Nottingham Health Profile; NSAID = non-steroidal anti-inflammatory drug; ORD = obesity related diseases; PA=physical activity; PD = pulmonary disease; QALY = quality adjusted life years; RYGBP = Roux-en-Y gastric bypass; SAH = systemic arterial hypertension; SG = sleeve gastrectomy; SOS = Swedish Obese Subjects study; T2DM = type 2 diabetes mellitus; TC = total costs; USD = United States Dollar; VAMC = Veterans Affairs Medical Centre; VAS = Visual Analogue Scale; VBG = vertical banded gastroplasty.

Author, year, country, currency, time horizon, discount rate.	Type of surgery.	Target group.	Main data source(s).	Comparator.	(N=x) at baseline.	Health care resource costs (hospital and primary care).	Patient and family costs and other sector costs.	HRQoL, HSUV.	Perspective.	Reoperation, complication, body-contouring (BC)	Study design, key effectiveness measure(s), key costs, partial or full economic evaluation.	Economic evaluation, quality rank and score (% or x/24).	Key summary measure(s), key finding(s).
Martin 1995 (39), United States, USD, 6 years.	RYGBP.	Morbid obesity BMI>40	Single treatment centre database, patient bills.	Very low calorie diet.	201 surgical, 161 Medical.	Yes.	No.	No.	Not stated.	Not included, BC not included.	Retrospective, observational, changes in BMI, direct medical costs hospital charges, pathology, radiology, surgeon, anaesthetics, diet, weekly behaviour therapy, partial economic evaluation.	CCA, low. 55%	Cost/pound weight loss. First large-scale comparison of surgical versus medical intervention. Year 6: medical \$1500/lb, surgical \$750/lb.
Narbro 1999 (77), Sweden, VBG, 5 years.	GB, VBG, GBP.	Age 37-60, men BMI ≥38, women BMI ≥34.	Swedish national insurance.	No surgery.	369 Surgical, 371 matched control.	No.	Yes.	No.	Not stated.	Included, BC not included.	SOS cohort (first 740 consecutive cases), weight lost in kg, adjusted mean number of days of sick leave and disability pension, partial economic evaluation.	CCA, medium 60%	Changes in sick leave and disability pension. Surgical treatment results in a decrease in sick leave and disability pension rates in participants aged 47-60.
van Gemert 1999 (102), Netherlands, USD, lifetime, DR=5%.	VBG.	Morbid obesity BMI>40.	Single treatment centre database, patient interviews,	No surgery.	21.	Yes.	Yes.	Yes. NHP I and II and VAS	Societal.	Included, BC not included.	Model: decision tree, QoL scores, weight loss (kg) and BMI, direct costs of surgical treatment, revisional surgery, medical appointments, diagnostic tests, hospital	COI, CUA, medium. 15/24	Cost/QALY. \$4004 to \$3928/QALY. Cost-effectiveness more dominant when productivity gains included.

Agren 2002 (111), Sweden, (1996 USD), 6 years. DR=3%.	GB, VBG, GBP.	Age 37-60, men BMI ≥ 38 , women BMI ≥ 34 .	Institute of Public Health. Swedish hospital data register.	CT.	481 surgical, 481 matched Control.	Yes.	No.	No.	Not stated.	Included, BC included.	costs, indirect costs of productivity losses, partial and full economic evaluation. SOS cohort (first 962 consecutive cases), average weight reduction, cost of inpatient care as average cost per day, partial economic evaluation.	CCA, medium. 60%	Mean inpatient care costs. TC (discounted) over 6 years surgical: \$9533 $\pm$ 10156, control \$2540 $\pm$ 6113. Average weight reductions of 16% will not reduce hospitalisation costs over 6 years. A substantial share of costs is because of secondary plastic surgery.
Craig 2002 (40), United States, (2001 USD), lifetime, DR=3%.	GB.	Age 35-55, BMI 40-50, non-smokers without CVD, major psychiatric disorders.	Healthcare cost and utilization project database.	No surgery.	NA	Yes.	No.	Yes. Model	Health care system/ third party payer	Included, abdominoplasty included.	Model: deterministic decision model, lifetime with reduced BMI, direct medical costs, surgery, follow-up care, treatment of complications, treatment of obesity related diseases, full economic evaluation.	CEA, CUA, high. 21/24	Cost/LY and Cost/QALY. GBP cost-effective. At age 55 years for BMI 40 (kg/m ²) Cost/LY men \$100200, women \$248500; Cost/QALY men \$35600, women \$16100 and for BMI 50 (kg/m ²) Cost/LY men \$30700, women \$38900; Cost/QALY men \$13300, women \$5400.
Narbro 2002 (80), Sweden, SEK and (2001 EURO), 6 years.	GB, VBG, GBP.	Age 37-60 years, men BMI ≥ 38 , women BMI ≥ 34 .	Questionnaires regarding prescribed medication use.	CT.	510 surgical, 455 Medical.	Yes. meds.	No.	No.	Not stated.	Not included, BC not included.	SOS cohort (first 1294 consecutive cases, only patients with complete 6 year follow up included), average weight loss of 16% in 6 years, medication costs for DM, CVD, NSAIDs/Pain, PD, anaemia, GID and other, partial economic evaluation.	CCA, high. 80%	Average annual medication costs. Surgical group lower medication costs for DM (69%) and CVD (31%). These savings balanced by increased medication costs for muscle inflammation, rheumatic disorders and pain, gastro-intestinal, anaemia and vitamin deficiency.
Gallagher 2003 (41), United States, USD, 2 years.	RYGBP.	Severely obese (BMI>50) primarily men, mean age 52 $\pm$ 2 years who underwent RYGB.	Veterans affairs medical records, admin database.	Before and after.	25.	Yes.	No.	No.	Health care system/ third party payer	Included, BC included (panniculectomy).	Retrospective, observational, direct medical inpatient and outpatient costs, partial economic evaluation.	CCA, low. 55%	Mean changes in costs. Reduced obesity related expenditures and utilisation of health care resources. Cost of all care excluding peri-operative charges 1 year post surgery \$2840 $\pm$ 622 per patient. Cost of undertaking RYGBP is offset by reduction of health care costs within the first year of surgery.
Christou 2004 (96), Canada, (1996 CAD), 5 years.	All types.	Morbidly obese treated with bariatric surgery with 6 matched	Single tertiary centre admin database, provincial	No surgery.	1035 surgery, 5746 matched control.	Yes.	No.	No.	Not stated.	Included, BC not included.	Retrospective, observational, weight loss as % initial excess weight loss and % initial BMI reduction, direct medical costs for each hospitalisation, physician	CCA, medium. 65%	Mean health care utilisation and total direct costs. Total direct costs surgery \$8813 (2344), control \$11854 (21220). Mean total direct health care costs were significantly higher in the controls for all specific diagnostic categories. Exceptions were costs for digestive

		controls per case.	insurance database.								visit and prescription medication, partial economic evaluation.		disorders where mean cost for bariatric patients was 68% higher than controls.
Gould 2004 (42), United States, (2003 USD), 6 months.	LRYPBP	Severely obese (mean BMI 51±2) primarily women medication CMs.	Single study centre, bariatric surgery database.	Before and after.	50.	Yes meds.	No.	No.	Not stated.	Not included, BC not included.	Prospective, observational, cost of prescription medication online pharmacy website, partial economic evaluation.	CCA, medium. 60%	CM related medication expenses and monthly cost-savings. Monthly savings of all medications \$120, DM \$63, HT \$37, hypercholestraemia \$86, GERD \$91, Depression \$0.
Monk 2004 (43), United States, USD, mean 16 months.	RYGBP	Morbidly obese (mean BMI 57) primarily women.	Single centre, hospital and follow up, pharmacy cost data.	Before and after.	64.	Yes meds and CPAP use.	No.	No.	Not stated.	Not included, BC not included.	Retrospective, observational, cost of monthly medications and CPAP equipment, partial economic evaluation.	CCA, low. 50%	Comorbidity medications and medical equipment monthly savings. Monthly savings CPAP equipment \$207, T2DM \$71, HT \$17, GERD \$34, asthma \$20, all CM \$182.
Potteiger 2004 (44), United States, USD, 14 months.	ORYGBP LRYPBP	BMI>40 with obesity related DM and HT, or BMI>45.	Single study centre database.	Before and after.	51.	Yes meds.	No.	No.	Not stated.	Not included, BC not included.	Retrospective, observational, prescription costs based on national wholesale pricing, direct hospital costs included clinicians, laboratory, hospital services, partial economic evaluation.	CCA, medium. 60%	Reduction in number and cost of DM and anti-HT medications. DM average reduction in monthly medication costs of \$109 and HT \$34 per month. Annualised pharmaceutical saving of \$1736.
Sampalis 2004 (97), Canada, (1996 CAD), 5 years.	RYGBP, VBG.	Morbidly obese (BMI 50±8) treated with bariatric surgery with 6 matched controls per case.	Single tertiary study centre database, provincial health insurance database.	No surgery	1035 surgery, 5746 control.	Yes.	No.	No.	Not stated.	Included, BC not included.	Retrospective, observational, % change in BMI, % change in EWL, direct hospital costs included all hospital charges, laboratory and clinician charges, partial economic evaluation.	CCA, medium. 75%	Net reduction >\$5.7 m for hospitalisations per 1,000 patients treated, within 5 years after surgery. Initial costs of surgery can be amortised over 3.5 years. Cost ratio for control: bariatric year 1: 0.29, year 2: 1.43, year 3: 4.28, year 4: 4.47, year 5 5.21.
Snow 2004 (45), United States, USD, 2.5 years.	LRYPBP	Age 55-75, morbidly obese (mean BMI 48) who underwent LRYGB.	Insurance database, patient prescription verified physician/primary care.	Before and after.	78.	Yes meds.	No.	No.	Not stated.	Not included, BC not included.	Retrospective, observational, medication cost obtained from 3 retail sources and averaged, partial economic evaluation.	CCA, medium. 60%	Change in medication costs. Decrease of 72% in prescription medication costs per patient per month at 2 years. Average annual cost savings for 78 patients \$240566.

Cendán 2005 (46), United States, USD, ICU LOS (mean 27 days).	All types.	Patient subgroup (19%) emergency or elective critical care.	Single tertiary centre, hospital data ICU resources and costs, medical records.	Before and after.	241.	Yes.	No.	No.	Not stated.	Included, BC not included.	Retrospective, observational, direct hospital costs including ICU and/or advanced medical care unit, partial economic evaluation.	CCA, medium. 70%	Costs for critical care admission (emergent and elective) following surgery and costs for each complication cluster (thromboembolic, pulmonary, anastomotic). DVT-PE increased cost of stay from \$29290±55000 to \$93000±77700; pulmonary from \$17200±13800 to \$69000±96300; anastomotic from \$27420 ±43200 to \$56200±100700. Approximately 20% require advance care units.
Finkelstein 2005 (2), United States (2004 USD), USD, Time to break even (mean 9.5 and 7.4 years) DR=3%.	All types.	Age 18-64 years, reported working ≥35 hours per week. BMI≥40 or BMI≥35<40 with CMs.	Medical Panel Expenditure Survey, National Health Interview Survey.	No surgery.	20329.	Yes.	Yes.	No.	Health care system/ third party payer	Not included, BC not included.	Model: two part simulation, estimated annual medical costs attributable to obesity for the surgery eligible and surgery ineligible populations and assumed price of the procedure \$25000, full economic evaluation.	CBA, medium. 18/24	Assuming a 75% reduction in obesity attributable costs, time to break even (at 90 th percentile of cost distribution) 5 years for medical and work loss costs. Simulations reveal that 5 or more years of follow up are most likely required for surgery to become cost-saving unless the employee bears a significant fraction of the total costs of the procedure.
Jensen 2005 (47), United States, (2004 USD), life course.	GBP.	Base-case morbidly obese white female, age 40, BMI≥40.	Published sources.	Diet/PA for 2 years at age 18 and BMI≥35.	346 surgery 212 Diet/PA	Yes.	Yes.	Yes. Model	Societal.	Included. BC not included.	Model: decision tree, direct medical costs included operating room, nursing, equipment, anaesthesia, pharmaceuticals, diagnostics tests, ORD-related direct medical costs. Complication costs assumed \$5000, full economic evaluation.	CUA, medium. 17/24	Cost/QALY. Base-case \$7126/QALY. GBP at age 40 is cost-effective compared with a diet and exercise based intervention at age 18 among a cohort of obese white females.
Mehrotra 2005 (48), United States, (2001 USD), 10 years.	GBP, GST, other by ICD codes.	Primary diagnosis of morbid obesity and weight loss surgery.	Inpatient hospital discharge data, health department database, Census population estimates.	Increases in charges by payer type.	269.	Yes.	No.	No.	Health care system/ third party payer	Included. BC not included.	Retrospective, observational, charges based on hospital or facility bills for patient care excluded professional fees such as surgeon or anaesthetic fees, partial economic evaluation.	CCA, medium. 70%	Inflation adjusted total charges for weight loss surgery by payer type (Medicare, Medicaid, private insurance, Self-pay). Despite a significant decline in the average length of stay in hospital after surgery, the inflation-adjusted average charge per procedure doubled from \$12006 to \$23629 from 1990/92 to 2000/02.
Ackroyd 2006 (90), France, Germany,	AGB, GBP.	BMI≥35 and T2DM in France,	HTA reports and HODaR	CT for T2DM.	1000.	Yes.	No.	Yes. EQ-5D	Health care system/	Included. BC not included.	Model: decision tree deterministic linear algorithm, combined	CEA, CUA, BIA,	Cost/QALY. Cost/T2DM-free year. Budget impact for 1000 patients. AGB and GBP are cost-effective at 5 year follow-up and cost-

United Kingdom, EURO, BPD, 5 years, DR=3.5%.	Germany and United Kingdom.	Cardiff Research Consortium database. Expert opinion.						third party payer		effectiveness of BMI reduction, T2DM remission and EQ-5D responses, unit costs in all countries based on identification of the main cost-driving inpatient and outpatient health care resources up to 5 years after surgery, full economic evaluation.	high. 23/24	saving in Germany and France. Cost-effective in the UK with a moderate budget impact versus CT. Germany GBP: €2455/QALY, €2208/T2DM free year, AGB: €1305/QALY, €576/T2DM free year; France GBP: €4000/QALY, €2118/T2DM free year, AGB: €1379/QALY, €609/T2DM free year; UK GBP: £2599/QALY, £1376/T2DM free year, AGB: £3251/QALY, £1434/T2DM free year.	
Gorman 2006 (49), United States, USD, 2 years.	ORYGB, LRYGB.	BMI≥40 and BMI≥35 with certain CMs.	Health plan database and chart review.	Before and after.	19.	Yes.	No.	Yes. SF-12	Health care system/ third party payer	Included. BC discussed but not included.	Prospective, observational, charges paid extrapolated from claims data included unrelated medical visits (e.g. obstetrics), partial economic evaluation.	CCA, low. 55%	Change in mean annual costs. Sample too small to draw definitive conclusions regarding cost reduction. Difference \$-1300 (5000); <i>p</i> = 0.29.
Nguyen 2006 (50), United States, USD, 2 years.	LAGB.	Morbidly obese on medication for at least one or more CM of HT, HLP, GERD, DM.	Single study centre database, medication history from patient and/or physician.	Before and after.	77.	Yes, meds.	No.	No.	Not stated.	Not included. BC not included.	Retrospective, observational, retail medication costs sourced from online pharmacy, partial economic evaluation.	CCA, medium. 65%	Mean monthly medication costs. One month postoperative medication cost saving GERD (81%), DM (69%), HLP (53%) and HTN (43%).
van Mastrigt 2006 (103), The Netherlands, (1999 EURO), 1 year.	VBG, LAGB.	Age 18-60, BMI>40 or BMI35-40 with significant CM. Excluded psychiatric, previous upper abdominal surgery.	RCT, hospital data and cost diaries.	Before and after.	50 VGB 50 LAGB	Yes	Yes	Yes. EQ-5D	Societal	Included. BC not included.	RCT, % EWL at 12 months and utility, costs individual direct medical and non-medical cost use of unpaid help and productivity losses (friction cost method), full economic evaluation.	CEA, CUA, medium. 19/24	Cost/%EWL and Cost/QALY. After one year, costs and QoL of two treatment modalities were found to be equal. €36834/QALY.
Hawkins 2007 (91), United Kingdom, BPD, 6 months.	LRYGBP LAGB	NHS patients.	Survey.	Before and after.	79.	No.	Yes.	No.	Not stated.	Not included. BC not included.	Retrospective survey regarding paid employment hours, intention to work and state disability benefits, partial economic evaluation.	CCA, medium 75%	Paid work and weekly hours worked. State benefits claimed before and after surgery. Average weekly time worked before 30.1 hours, after 35.8 hours (<i>p</i> <0.01). One-quarter decrease in the number of state benefits

Wagner 2007 (51), United States, mean 44 months.	RYGBP	Age<65, medically disabled morbidly obese receiving Medicaid.	One study centre, Medicaid recipients.	No surgery.	38 surgery 16 control	No.	Yes.	Yes. SF-36	Not stated.	Not included. BC not included.	Retrospective survey regarding patients who are working and not claiming Medicaid benefits. Mean excess BMI lost, partial economic evaluation.	CCA, medium. 70%	claimed after surgery. Number and % Medicaid recipients who return to work. 37% Medicaid-funded patients returned to work compared to 6% of patients from the non-surgical control group.
Cremieux 2008 (52), United States, (2005 USD), 6 years, DR=3.07%.	OGBP, OGB, LGBP, LGB.	Morbidly obese, age>18 years.	Privately insured claims database 5 million lives, 31 companies.	No surgery.	3651 surgery 3651 control	Yes.	No.	No.	Health care system/ third party payer	Included. BC not included	Retrospective, observational, CM reduction (BMI data unavailable in insurance claims database), costs direct medical including prescription drug and medical service (inpatient, emergency department, outpatient, office), partial economic evaluation.	ROI, medium. 75%	ROI. Initial investment approximately \$26000 open and \$17000 laparoscopic surgery. Initial investment is returned within 4 years for open surgery and within 2 years for laparoscopic surgery.
Hodo 2008 (53), United States, USD, 1 year.	ORYGBP LRYGBP	Morbidly obese with CMs, continuous enrolment for 12 months.	Managed care organisation database.	Before and after.	605.	Yes.	No.	No.	Not stated.	Not included. BC not included.	Retrospective, observational, Charlston CM index, medication use/costs, health service use/costs included office, inpatient and outpatient visits, emergency room, prescriptions, partial economic evaluation.	CCA, low. 50%	Mean medication use and costs and claims for specific health services. Medication use and costs decreased within 6 months of bariatric surgery. Pharmacy costs decreased 28% in 6 months after surgery. Health services use greatest decrease in claims (47%) for outpatient visits.
Salem 2008 (54), United States, (2004 USD), lifetime, DR=3%.	LAGB LRYGBP	Base-case morbidly obese male and female BMI≥40, age 35 years.	Published and unpublished sources.	No surgery.	NA	Yes.	No.	Yes. Model	Health care system/ third party payer	Included. Abdomi-noplasty included.	Model: deterministic decision analytic, survival and weight loss, direct medical costs, full economic evaluation.	CUA, high. 20/24	Cost/QALY <\$25000 for both procedures. LRYGB and LAGB cost-effective when evaluating the full range of BMI values and estimates for adverse outcomes, weight loss and costs.
Anselmino 2009 (99), Austria Italy, Spain, EURO, 5 years, DR=3.5%.	AGB, GBP.	Patients with BMI ≥35 and T2DM in Austria, Italy and Spain.	Published and unpublished sources.	CT.	1000.	Yes.	No.	Yes EQ-5D (90)	Health care system/ third party payer	Included. BC not included.	Model: decision tree, annual BMI variation and T2DM prevalence variation (medications and complications) up to 5 years after bariatric surgery. Adopted Ackroyd (90) cost methodology, full economic evaluation.	CEA and CUA, medium. 18/24	Cost/QALY, Cost/T2DM free year. Base-case AGB and GBP inpatients with baseline T2DM cost-saving in Italy and Austria and cost-effective in Spain. Worst case €/QALY AGB Austria €-1,680/QALY; Italy €638/QALY; Spain €3,142/QALY. Worst case GBP Austria €-301/QALY; Italy €94/QALY; Spain €4,347/QALY. Worst case €/T2DM-free-year

Ikramuddin 2009 (55), United States, (2007 USD), 35 years, DR=3%.	RYGBP.	Severely obese with T2DM, matched cohort.	Single academic medical centre, published and unpublished sources.	Standard care.	2223 567 (T2DM or pre-diabetes)	Yes.	No.	Yes. EQ-5D	Health care system/ third party payer	Included. BC not included.	Model: CORE Diabetes model (Markov structure) used Monte Carlo simulation and tracker clinical endpoints included, BMI, HbA1c, lipids, SBP and medication use, direct medical costs from published sources, full economic evaluation.	CEA, CUA, high. 20/24	AGB Austria €-741/T2DM-free-year; Italy €281/ T2DM-free-year; Spain €1,390/ T2DM-free-year. Worst case GBP Austria €-159/T2DM-free-year; Italy €50/ T2DM-free-year; Spain €2,302/ T2DM-free-year. Cost/QALY. Cost/LY gained. \$21973/QALY and \$29676 LY gained. RYGBP cost-effective in the treatment of T2DM. Sensitivity analyses indicated surgery is not cost-effective over shorter time horizons, or if the negative quality of life impacts of increased BMI is ignored.
Keating 2009 (85), Australia, (2006 AUD), 2 years.	LAGB.	Class I and II (BMI>30 and <40) recently diagnosed <2 years T2DM.	RCT: resource use trial data and medical records. Unit costs private hospitals, specialists, MBS and PBS.	CT.	30 surgery 30 control	Yes.	No.	No.	Health care system/ third party payer	Included. BC not included.	RCT: within trial efficacy results included remission of diabetes, within trial intervention costs included LAGB surgery costs, mitigation of complications, outpatient medical, medical investigations, pathology, weight loss therapies and medication, full economic evaluation.	CEA, high. 22/24	Within trial cost efficacy cost/case of T2DM remitted. Time horizon of 2 years an additional \$16600 of direct health care investment is required to remit an additional case of recently diagnosed T2DM through LAGB. CT \$25000/case of T2DM remitted.
Keating 2009 (86), Australia, (2005 AUD), lifetime (or age 99 years), DR=3%.	LAGB.	Class I and II (BMI>30 and <40) recently diagnosed <2 years T2DM.	Published within trial RCT cost and efficacy data. Other published sources including MBS and PBS.	CT.	30 surgery 30 control	Yes.	No.	Yes. EQ-5D	Health care system/ third party payer	Included. BC not included.	Model: builds on a within trial CEA by extrapolating cost and outcomes. Markov model that is representative of the natural history of T2DM, mean annual health care costs for people with T2DM, full economic evaluation.	CEA, CUA, high. 24/24	Cost/LY gained. Cost/QALY. Mean healthcare saving of \$2400 and 1.2 additional QALY's per patient. Surgery dominant intervention for managing recently diagnosed T2DM in class I/II obese patients in Australia.
Ananthapavan 2010 (84), Australia, AUD,	LAGB.	Severely obese (BMI≥35) privately insured	Medical records for resource use and published	Standard care.	Data from 28 adolescents modeled	Yes.	Yes.	No.	Societal.	Included. BC not included.	Model: Markov, change in BMI, direct medical resource use of 28 patients and extrapolated for eligible population, time spent by	CEA, CUA, high. 21/24	Cost/DALY saved. Cost/BMI unit saved. Cost \$130 million resulted in incremental savings of 55,400 BMI units at 3 years after surgery. \$4400/DALY. LAGB cost-effective for adolescents.

lifetime, DR=3%.	adolescents (age 14-19 years).	sources for unit costs.			for 4120 severely obese.						both parents for travel and consultation accompanying their adolescent, cost offsets using disease costs estimates, full economic evaluation.		
Campbell 2010 (26), United States, (2006 USD), lifetime, DR=3%.	LAGB, LRYGB.	Morbidly obese adults aged 18-74 years BMI $\geq$ 35 with CMs or BMI $\geq$ 40.	Published sources supplemented by clinical expert opinion.	No surgery.	NA	Yes.	No.	Yes. EQ-5D	Health care system/ third party payer.	Included. BC not included.	Model: Markov, cumulative change in BMI, direct medical inpatient and outpatient costs, full economic evaluation.	CEA, CUA, high. 23/24	Cost/QALY. Cost/LY saved. Both LAGB and LRYGB versus no treatment <\$25000/QALY gained but highly sensitive to model assumptions. ICERs lower for individuals with higher initial BMIs and higher for older individuals. ICERs for men generally higher than for women.
Hoerger 2010 (56), United States, (2005 USD), lifetime (or 95 years), DR=3%.	GBP, GB.	Severely obese adults BMI $\geq$ 35 with newly diagnosed or established DM.	National Health and Nutrition Examination Survey and published sources.	No surgery.	NA	Yes.	No.	Yes. Model	Not stated.	Included. Abdominoplasty included.	Model: simulation - expanded Centres for Disease Control and Prevention-RTI Diabetes Cost-Effectiveness Model to incorporate bariatric surgery, diabetes remission and improvement along micro (nephropathy, neuropathy and retinopathy) and macro vascular (CHD and stroke) pathways, direct costs of newly diagnosed and established T2DM, full economic evaluation.	CUA, high. 22/24	Cost/QALY. Cost/case of T2DM remitted. Newly diagnosed T2DM: bypass surgery \$7000/QALY, banding surgery \$11000/QALY. Established diabetes: bypass surgery \$12000/QALY, banding surgery \$13000/QALY. Relative to the newly diagnosed diabetic population, bariatric surgery led to fewer life-years gained and higher incremental cost-effectiveness ratios within the established diabetic population.
Maciejewski 2010 (57), United States, (2006 USD), 6 years.	All types.	Morbidly obese mostly high risk older males (veterans).	Multisite Veterans Affairs Medical Centres.	No surgery	846.	Yes.	No.	No.	Health care system/ third party payer.	Included. BC not included.	Retrospective, observational, costs inpatient and outpatient healthcare utilization and expenditures (including medications), partial economic evaluation.	CCA, medium. 80%	Mean inpatient, outpatient and total costs. Unadjusted inpatient expenditures averaged \$1805 per person 3 years before surgery, increased to \$27536 in the surgical year, and declined in the years after surgery (mean \$5538 1 year after surgery and \$2374 3 years after surgery; unadjusted average outpatient expenditures \$985 3 years before surgery, \$3050 in the surgical year, \$1865 1 year after surgery, \$1203 3 years after surgery). Average overall expenditures \$6029 3 years prior to surgery, \$36176 in the surgical year, \$11893 1 year after surgery, \$6787 3 years after surgery.
Makary 2010 (58), United States, USD,	All types.	Aged 18-64 years, with T2DM who	Large insurance database	Before and after.	2235.	Yes.	No.	No.	Not stated.	Not included. BC not	Retrospective, observational, use of diabetes medications at specified post-operative time	CCA, medium. 65%	Changes in median annualised costs per patient. Baseline average cost per patient \$6376, total annual healthcare costs in the first

3.5 years.		underwent bariatric surgery.	across 7 states.							included.	points, total direct health care costs defined as total payout by the insurer for health care claims included hospitalisations, procedures, medications, outpatient visits, consultations and other, partial economic evaluation.	3 years after surgery increased by 9.7% (\$616) in year 1, decreased by 34.2% (\$2179) in year 2 and decreased by 70.5% (\$4498) in year 3. Metformin greatest medication decrease with 52.9% taking metformin 3 months before surgery and 8.4% taking it 1 year after surgery.	
McEwen 2010 (59), United States, USD, 2 years and lifetime. DR=3%.	ORYGBP LRYGBP	Morbidly obese adults who underwent bariatric surgery.	Claims single managed health care plan, seven bariatric centres of excellence, post-operative survey data.	Standard care.	221.	Yes.	Yes.	Yes EQ-5D	Health care system/ third party payer.	Included. BC included.	Model: simulation, change in BMI, change in utility (preoperative quality of life assessed postoperatively), total direct medical costs subdivided into 7 mutually exclusive categories outpatient pharmacy, inpatient, outpatient clinic, diagnostic testing, laboratory testing, emergency room, and other, full economic evaluation.	CUA, medium. 18/24	Cost/QALY. At 2 years \$49000/QALY gained. Over lifetime \$1400/QALY gained. Long term cost-effectiveness appears to depend on the natural history and cost of late postsurgical complications and the natural history and cost of untreated morbid obesity.
Mullen 2010 (60), United States, (2007 USD), 85 months.	ORYGBP LRYGBP		Claims and membership enrolment metro-politan health plan.	No surgery.	224.	Yes.	No.	No.	Health care system/ third party payer.	Included: DRG not specific to bariatric surgery. BC not included.	Retrospective, observational, change in BMI, costs all hospital, outpatient services, professional services and pharmacy charges, partial economic evaluation.	CCA, medium. 70%	Comparison of average annual costs. RYGB breakeven point for surgery 3.5 years and surgery cohort used fewer healthcare resources after surgery.
Perryman 2010 (61), United States, (2008 USD), 2.5 years. DR=4%	LAGB.	Age>18 years and bariatric surgical eligibility criteria: BMI≥35 with CMs and BMI≥40.	Employees' retirement system database, published sources.	No surgery.	14100.	Yes.	Yes.	No.	Health care system/ third party payer. Societal.	Included. BC not included.	Model: dynamic input-output, theoretical candidates for LAGB calculated based on national data and eligibility criteria for LAGB, direct health costs and related absenteeism, impacts comprise the costs and benefits of direct, indirect and induced economic impacts, full economic evaluation.	CBA, ROI, medium. 18/23	Payback period and average annual ROI. Economic impact assessment. Payback period 23-24 months from the payer perspective, employer perspective 17-19 months. From a societal perspective the impact on total business activity for Texas (over 5 years) included gains of \$195.3 million in total expenditures, \$93.8 million in gross product, and 1354 person-years of employment.
Roger-Anderson	DS.	Age 18-60, Morbidly	Self-report of paid	Before and after.	51.	No.	Yes.	Yes SF36	Not stated.	Not included.	Prospective self-report of paid workforce participation,	CCA medium.	Hours of paid work per week. Number of patients who performed paid work was

2010 (100), Norway, 2 years.		obese (BMI ≥ 35 with CMs or BMI ≥ 40) accepted for DS at single study centre.	workforce participation.							BC included (panniculectomy).	% excess BMI loss, paid work on scale 0-100% where 100% is full-time work (37.5 hours per week), partial economic evaluation.	70%	unchanged year 0 to year 1. Increased from 54.9% at year 0 to 66.7% at year 2. Percentage of the patients performing paid work at year 2 was lower than the population norm (82%).
Chang 2011 (10), United States, (2010 USD), lifetime, DR=3%.	All types	BMI ≥ 35 , two groups with/without ORD.	National Health and Nutrition Examination Survey, published sources.	No surgery.	NA	Yes.	No.	Yes BQL	Health care system/ third party payer.	Included. BC not included.	Model: Mixed Proportional Hazards model and simulation, costs from published studies included average costs without revision, average costs of medical complication and reoperation and perioperative death, and relationship between BMI and associated costs of ORDs, full economic evaluation.	CEA, CUA, high. 22/24	Cost/LY and Cost/QALY. For BMI ≥ 35 <\$4000/QALY, Cost-saving for super obese (BMI ≥ 50) with obesity related CMs. Sensitivity analysis BMI 30-35 found that ICER increases \$350/QALY gained for non-ORD group and \$500/QALY gained for the ORD group. Sensitivity analysis found that costs-effectiveness analyses are particularly sensitive to cost data.
Clough 2011 (87), Australia, 25.5 months.	LAGB.	Bariatric surgery patients age >60 years, mean BMI 42.2.	Single surgeon's clinic/ hospital records, LapBase database.	Before and after.	113.	Yes meds	No.	Yes SF36	Not stated.	Included. BC not included.	Retrospective, observational, change in medication use for comorbidities including diabetes, HT, sleep apnoea, hyperlipidaemia, reflux, asthma/COAD partial economic evaluation.	CCA, medium. 70%	Mean medication use at baseline, significant average medication reduction (diabetes, HT, sleep apnoea, hyperlipidaemia, reflux, asthma/COAD) was not shown in this study. Marked improvement in QoL after LAGB surgery in the obese elderly was the key positive finding.
Cremieux 2011 (62), United States (2010 USD), 124 months.	GBP, RYGBP, LAGBP.	Age 18-64 years, BMI ≥ 35 , DM.	Administrative claims database, 13.5 million lives, 58 companies.	No surgery.	2059 surgery 2059 control	Yes.	No.	No.	Health care system/ third party payer.	Not included. BC not included.	Retrospective, observational, medication utilisation, total direct healthcare costs and medication claims, investment in bariatric surgery is the sum of all incremental costs incurred in the month before, the month of and the month after surgery, relative to the total healthcare costs of control patients, partial economic evaluation.	ROI, medium. 75%	ROI. Updated analysis confirms that on average cost savings begin to accrue to third party payers at 3 months after surgery for T2DM patients. Surgery costs were fully recovered at 47 months (95% CI 34-61) for laparoscopic surgeries.
Ewing 2011 (63), United States (2008	LGBP, LAGB.	Bariatric surgery patients	Administrative hospital	No surgery.	150.	Yes.	Yes.	No.	Societal.	Not included. BC not	Model: input-output model of a regional economy, ongoing improvements in worker	CBA, medium. 17/24	Net Present Value. Net benefit \$1.3 (DR=10%) to \$9.9 B (DR=3%) USD to a regional economy. Net benefit consists of upfront costs

USD), DR=3,5,10%.		from a single site.	data from single site, published sources.							included.	productivity, costs expressed in terms of lost output, labour income, employment, and indirect business taxes, full economic evaluation.		of surgical treatment and ongoing gains from improvements in worker productivity.
Finkelstein 2011 (64), United States (2008 USD), USD, 5.7 years.	LAGB.	Age 18-64 years and diabetes subsample. LAGB mean BMI=44.5, comparison sample mean BMI=44.8.	Admini- strative claims database.	No surgery.	7310 surgery 7310 control	Yes.	No.	No.	Health care system/ third party payer.	Included. BC not included.	Retrospective, observational, Cost quarterly payments of total, inpatient (both facility and physician), non-inpatient including hospital, outpatient, physician office, emergency department), and prescription medication claims, partial economic evaluation.	ROI, medium. 75%	Breakeven time horizon for LAGB sample and diabetes subsample. Initial payments for LAGB were fully recovered within 4 years and in just over 2 years for the diabetes subsample.
Finkelstein 2011 (65), United States, USD, 5 years.	LAGB.	Age 18-64 years, DM subsample.	Medical Expenditure Panel Survey and National Health and Wellness Survey, published sources.	No surgery.	2298.	Yes.	Yes.	No.	Not stated.	Included. BC not included.	Retrospective observational, estimation of elasticities for absenteeism, presenteeism, direct medical costs, absenteeism costs and presenteeism costs, partial economic evaluation.	ROI, medium. 75%	Time to breakeven for LAGB sample and diabetes subsample. Inclusion of indirect costs does not substantially change the breakeven period from 2 years found in previous study. Beyond the breakeven period there are additional indirect cost savings that accrue to employers. After 5 years net savings increase from \$26570(±\$9000) to \$34000(±\$10380).
Kelles 2011 (105), Brazil (2005 USD), 2 years.	RYGBP.	Morbidly obese patients who underwent bariatric surgery, mean BMI=43.	HMO database.	Before and after.	382.	Yes.	No.	No.	Health care system/ third party payer.	Included. BC not included.	Retrospective observational, direct medical costs, partial average cost calculated as total cost minus costs 3 months before and after surgery, partial economic evaluation.	CCA, medium. 65%	Mean cost of surgery and mean total cost of healthcare services per patient. Partial average cost almost doubled after the operation (\$392 versus \$678). Patients presenting with HT, DM, BMI≥50 and aged >50 years have significantly higher costs than patients without these conditions.
Klein et al 2011 (66), United States, (2007 USD), 90 months, DR=3.4%.	All types.	Aged 18-65 years, BMI≥35, DM.	Admini- strative claims covering 8.5 million lives 40 companies.	No surgery.	808 surgery 808 control	Yes.	No.	No.	Health care system/ third party payer.	Not included. BC not included.	Retrospective, observational, 3 outcome measures diagnostic claims for diabetes, claims for diabetes medication, average total costs of diabetes medication and supplies, costs direct medical including medication	ROI, high. 80%	ROI. Therapeutic benefits of bariatric surgery on diabetes translate into considerable economic benefits. Surgery costs were recovered at 30 months (for open and laparoscopic surgeries).

											costs, partial economic evaluation.		
Maklin 2011 (109), Finland, (2010 EURO), 10 years, DR=3%.	GBP, SG, GB.	Morbidly obese with higher prevalence of T2DM.	Administrative hospital data, expert opinion of surgeons, population health survey, published sources	Standard care.	NA	Yes.	No.	Yes 15D	Health care system/ third party payer.	Included. Abdominoplasty included.	Model: decision tree and Markov model, decline in BMI based on EWL data, T2DM and sleep apnoea, costs based on average costs for each procedure type in the DRG and average annual costs for both treatment groups, excluding cost of medication, full economic evaluation.	CUA, High. 22/24	Cost/QALY. Bariatric surgery cost-effective. Mean costs were €33870 and €50495 and mean QALYs 7.63 and 7.05 for bariatric surgery and ordinary treatment respectively. Bariatric surgery dominant in sensitivity analysis. Strong dominance of bariatric surgery over ordinary treatment was removed if BMI at baseline was ≤ 38 .
Bleich 2012 (67), United States, (USD), 6 years.	All types.	Age 18-64 years with T2DM.	Administrative insurance data from 7 plans.	Before and after.	6376.	Yes.	No.	No.	Health care system/ third party payer.	Not included. BC not included.	Retrospective, observational, costs included inpatient, outpatient, pharmacy and other (professional office and professional other), partial economic evaluation.	CCA, Medium. 80%	Means and medians for costs and utilisation measures for individuals with DM before and after surgery. Total mean costs for up to 6 years after having bariatric surgery, individuals with T2DM are more likely to have higher health care expenditures (total mean costs were \$9326 presurgery, \$13400 1 year after surgery, and \$13644 6 years after surgery), are more likely to have hospitalisations but are less likely to have primary care and specialist visits compared with their respective costs and utilization before surgery. Comparing no surgery with 3000 surgeries per year results in a net budget impact of a average of SEK 121 million per annum or SEK 40000 per patient. This implies that a 55% of the cost of surgery, has been offset by a reduction in the excess treatment costs of obesity related diseases.
Borg et al 2012 (83), Sweden, SEK, 10 years.	All types.	Overweight and obese from the adult Swedish population BMI>25, age 15-84 years.	Published sources.	Before and after.	NA	Yes.	No.	No.	Health care system/ third party payer.	Included. Costs of follow-up plastic surgery included.	Model: Markov and micro-simulation, changes in BMI, costs attributable risks to obesity related comorbidities, costs inpatient costs, full economic evaluation.	BIA, low. 55%	Comparing no surgery with 3000 surgeries per year results in a net budget impact of a average of SEK 121 million per annum or SEK 40000 per patient. This implies that a 55% of the cost of surgery, has been offset by a reduction in the excess treatment costs of obesity related diseases.
Finkelstein 2012 (68), United States, USD, 5 years.	LAGB.	Age 18-64 years. DM subsample.	Medical Expenditure Panel Survey and National Health and Wellness	No Surgery.	2298.	Yes.	Yes.	No.	Not stated.	Included. BC not included.	Retrospective, observational, estimation of elasticities for absenteeism presenteeism direct medical costs, cost estimates for absenteeism and presenteeism, partial economic evaluation.	ROI, medium. 80%	Time to breakeven and 5 year net costs of LAGB. Using all three cost categories (medical expenditures, absenteeism and presenteeism), the time to breakeven is reduced from 16 to 14 quarters (6 months). Beyond the breakeven period estimated savings are much larger when indirect costs are

			Survey. Published sources.										considered.
Ghiassi 2012 (69), United States, USD, 1 year.	RYGBP	Morbidly obese with DM and HT who had undergone RYGBP and taking DM and HT meds. Mean BMI=47. Mainly male cohort.	Medical records of consecutive patients at a single site – Veteran's Affairs health care system.	Before and after.	106.	Yes meds	No.	No.	Health care system/ third party payer.	Not included. BC not included.	Retrospective, observational, progression, improvement, or remission of DM or HT was determined at 1 year after surgery and %EWL, costs current Veterans Affairs pharmacy subsidised cost for each medication, partial economic evaluation.	CCA, medium 70%.	Mean annual costs of medications to treat HT was reduced by 65% at 1 year of surgery and 88% for DM. In a subset of patients with persistent HT of DM after surgery, cost reduction 58% for HT and 69% for DM.
Gripeteg 2012 (81), Sweden, GBP, 20 years.	GB, VBG.	SOS cohort: Age 37-60 years, men BMI≥38, women BMI≥34.	Swedish Social Insurance Agency.	Standard Care.	2901.	No.	Yes.	No.	Not stated.	Not included. BC not included.	SOS cohort, % weight change, incidence and number of disability pension days, partial economic analysis.	CCA, medium 75%	Incidence of disability pension and number of disability pension days over 10 years. Bariatric surgery may be associated with favourable effects on disability pension for up to 19 years in men whereas neither favourable nor unfavourable effects could be detected in women.
Maciejewski 2012 (70), United States USD, 6 years.	RYGBP.	Morbidly obese mainly high risk older male patients (veterans).	Multisite VAMCs.	No surgery.	847 surgery 847 control	Yes.	No.	No.	Health care system/ third party payer.	Included. BC not included.	Retrospective, observational, costs total veterans affairs expenditure sum of inpatient and outpatient expenditures, partial economic evaluation.	CCA high 85%	Mean inpatient, outpatient and total costs. Adjusted total expenditures converged in the 3 years after surgery, from \$4397 higher in the first 6 postsurgical months to similar expenditures in the 31 to 36 postsurgical months. Bariatric surgery was not associated with reduced expenditures in this cohort of older, predominantly male patients 3 years after the procedure.
Michaud 2012 (20), United States, (2010 USD), 46 years DR=3%.	Focus on RYGBP.	Age 50 years, BMI>40 or BMI35-40 with qualifying CMs and BMI 30-35 with qualifying	Published sources.	No surgery.	NA	Yes.	Yes.	No.	Societal.	Included. BC not included.	Model: Future Elderly Model (micro-simulation model), % weight loss, health care costs (private, Medicare and Medicaid); tax revenue; social security expenditures (disability and old-age pensions), full economic evaluation.	CEA high 24/24	Net present value per capita amongst eligible patients. Cost/LY gained. Present value of total medical costs for people who have had bariatric surgery is reduced by \$4649: \$3247 accrues to Medicare, \$276 to Medicaid and \$1126 to other (private) sources. On balance, bariatric surgery generates substantial private value for those treated. Net public fiscal effects are modest, primarily because the size of the population eligible for treatment is small. Net

Myers 2012 (71), United States, USD, 8 years.	LRYGBP	pre-existing conditions – DM. Severely obese BMI 40-60, aged 35-60 years. Single site and single surgeon.	State managed health insurance agency.	No surgery.	39 surgery 911 no surgery	Yes.	No.	No.	Health care system/ third party payer.	Included. BC not included.	Retrospective, observational, % EWL, medical costs included all medical claims (office visits, ED, laboratory/pathology, physical and occupational therapy, sleep facilities and remaining) except pharmacy claims. Pharmacy costs included direct pharmaceutical expenditure, partial economic evaluation..	CCA, high. 85%	Changes in mean medical and pharmacy costs per person per year. Combining total costs across the eight years of the study total medical costs for the non-surgical group were \$73212. The surgical group's costs were \$77894, which included the \$25000 cost of the surgery. Surgery costs may begin to be recouped within the first 4 years after surgery with continued effects 6 years after surgery.
Neovius 2012 (82), Sweden, GBP, (2011 USD), 20 years.	GB, VBG.	SOS cohort: Age 37-60 years, men BMI ≥ 38 , women BMI ≥ 34 .	National Patient Register and Prescribed Drug Register	CT.	2010 surgery 2037 control	Yes meds.	No.	No.	Not stated.	Included. BC not included.	SOS study, % weight loss, hospitalisation frequency, hospital days by year and non-primary outpatient care, partial economic evaluation.	CCA, high. 90%	Health care use and medication cost. Surgically treated patients used more inpatient and non-primary outpatient care during the first 6 year period after undergoing bariatric surgery but not thereafter. Drug costs from years 7 to 20 were lower for surgery patients than for controls. From year 7 to year 20, the surgery group incurred a mean annual drug cost of \$930; control patients \$1123.
Sussenbach (106), 2012, Brazil, (2011 USD), 3 years.	RYGBP	Bariatric surgery patients with T2DM, SAH and dyslipid-aemia.	Single study centre medical charts.	Before and after.	194.	Yes.	No.	No.	Health care system/ third party payer.	Not included. BC not included.	Retrospective, observational, improvement or resolution of CMs (three groups), costs excluded costs of the surgery, preoperative costs followed the recommendations of standardised guidelines for each CM, postoperative costs calculated according to information on medical charts e.g. doctors visits, examinations and tests and medications, partial economic evaluation.	CCA, medium. 70%	Annual costs before and after surgery. Annual median expenses for medications, professional care and examinations in the preoperative period were \$1706. In the postoperative period these expenses were \$1174 in the first 12 months, \$713 for 13-24 months and \$431 for 25 to 36 months.
Zanela 2012 (107), Mexico, (2011 PESO),	All types.	Adults, class II obese (BMI ≥ 35), at least one	Mexican Social Security Institute	No surgery.	150 surgery 150 control	Yes.	No.	No.	Health care system/ third	Not included. BC not included.	Model: discrete event simulation, comorbidity resolution at a different rate over time (resolution and re-	ROI, high. 90%	ROI time or cost of breakeven point 6.8 years. Total costs for the surgical group were 52% less than conventional treatment group after 10 years. Bariatric surgery reduced the

10 years, DR=4.5%.		CM, previous failed CT.	DRG list. Mexican National Institute of Public Health.						party payer.		incidence of T2DM, HT and hypercholesterolemia), costs inpatient, outpatient, pharmacy partial economic evaluation.		cost of treating T2DM, HT, and hypercholesterolemia by 59%, 53%, and 65%, respectively. ROI for bariatric surgery in patients with T2DM as the only comorbidity was 4.4 years.
Faria 2013 (101), GB, GBP. Global/Portugal, EURO. lifetime, DR=3%.		Morbidly obese with and without CMs, Baseline mean BMI=46.9.	Administrative hospital data and published sources.	CT.	NA	Yes.	Yes	Yes.	Societal.	Included. BC not included.	Model: Markov, weight loss and control of comorbidities, societal costs extracted from published sources and an institutional database, full economic evaluation.	CUA, medium. 19/24	Cost/QALY. Compared to the best medical management, in the global population of patients with a BMI of >35 kg/m ² , surgery rendered 1.9 extra QALYs and saves on average €13244 per patient. Younger patients, patients BMI 40 - 50 kg/m ² , and patients without ORD derive greater benefit.
Finkelstein 2013 (72), LAGB LRYGB United States, USD, 10 years, DR=		Morbidly obese who underwent bariatric surgery and DM subsample.	Insurance claims database	No surgery	9631 surgery; 9639 No surgery – MO code sample; DM 2447.	Yes	No	No	Not stated	Included. BC not included.	Retrospective, observational, Costs person-specific quarterly payments of total, inpatient (facility and physician), non-inpatient (including payments for hospital outpatient, physician's office visits, and ED), and prescription drug claims, partial economic evaluation.	ROI medium. 80%	Time to breakeven and net costs. Net costs and time to breakeven resulting from bariatric surgery are less favourable than has been reported in prior studies. Even with a more conservative and likely more accurate comparison sample, the business case for LAGB appears favourable. Without the morbid obesity code comparison sample, time to breakeven for LAGB increases to 5.25 years with a 5 year net cost of \$690.
Karim 2013 (94), LAGB Scotland, 2 years.		Obese adults BMI≥35, age 18-65 years who underwent LAGB.	Single site hospital database. Individual case notes.	Before and after.	73.	Yes.	No.	No.	Not stated.	Included. BC not included	Retrospective, observational, utilisation and costs hospital admissions, outpatient clinics, medications (DM, HT and analgesia), partial economic evaluation.	CCA, medium. 70%	Changes in utilisation of hospital services and associated costs. Total estimated costs savings ranged between \$32593 and \$41177 per annum.
Karim 2013 (95), LAGB, LRYGB, LSG. Scotland, GBP, 2 years.		Morbidly obese patients age 25-65 years who underwent bariatric surgery.	Single site hospital medical records and patients' GPs.	Before and after.	88.	Yes.	No.	No.	Not stated .	Included. BC not included.	Retrospective, observational, costs hospital inpatient, outpatient clinic and meds, partial economic evaluation.	CCA, medium. 70%	Summary of annual cost savings. Total annual cost savings £30404. Annual cost savings medications £11452, hospital admissions £16420 and £2532 outpatient clinics.
Keating 2013 (88), LAGB. Australia (2009 AUD),		Population of Australians	Australian government Medicare	Before and after.	9542.	Yes meds.	No.	No.	Health care system/	Not included. BC not	Retrospective, observational, costs pharmaceutical data classified into 8 therapeutic	CCA, high. 90%	Mean annual costs per person for prescription medication. Net reduction in pharmaceutical utilisation from 10.5 to 9.6 pharmaceuticals

4 years.		undergoing LAGB in 2007.	database.						third party payer	included.	categories. Unit costs paid by Medicare, partial economic evaluation.		prescribed per person/year, and costs decreased from \$517 to \$435.
Lam 2013 (73), United States, USD, 1 year.	LRYGBP	Morbidly obese Native Hawaiians who underwent LRYGB.	Medical records from single site.	Before and after.	50.	Yes meds.	No.	No.	Health care system/ third party payer.	Not included. BC not included.	Retrospective, observational, successful weight loss >50% excess body weight lost at one year postoperatively, costs medications from online pharmacy for 30 day supply of prescription medications, partial economic evaluation.	CCA, Medium 70%.	Average monthly and annual cost changes of prescription medications. Average number of prescription medications decreased from 3.5 per patient preoperatively to 1.1/patient at one year, monthly cost saving \$196.
Lee (89), 2013, Australia, (2003 AUD), lifetime, DR=3%.	LAGB	Population study: morbidly obese Australians BMI>35 and BMI>40	Published sources.	No surgery.	NA	Yes.	Yes.	No.	Health care system/ third party payer Societal.	Included. BC not included.	Model: Markov, costs intervention costs from previous published studies, time and travel costs 25% of hourly wage rate and disease costs, full economic evaluation.	CEA, high. 23/24	Cost/DALY averted. For BMI>35 \$2154/DALY averted. LAGB cost-saving when provided to all individuals with BMI>40. Cost-effective when extended to all individuals with BMI>35, but at a substantial aggregate cost. Results highly sensitive to changes in the likelihood of long-term complications.
Pollock 2013 (92), United Kingdom, BPD, 5 years.	LAGB.	Morbidly obese patients with newly diagnosed <2 years T2DM.	RCT data. Published sources.	Standard care.	100 surgery 100 no surgery	Yes	No	No	Health care system/ third party payer.	Included. Abdomi-noplasty included.	Model: budget impact model, reduction in BMI, HbA1c and SBP, costs inpatient, outpatient and medications, partial economic evaluation.	CCA, medium 80%	Cost savings of £913 per patient for LAGB over 5 years compared with standard medical management for newly diagnosed T2DM.
Pollock 2013 (93), United Kingdom, (2010 BPD), 40 years, DR=3.5%	LAGB	BMI = 30-40, recently diagnosed T2DM.	RCT data. Published sources	Standard care.	1000.	Yes.	No.	Yes.	Health care system/ third party payer.	Included. BC not included.	Model: CORE diabetes and nonparametric bootstrapping, RCT data: glycaemic control at the end of two years, % change HbA1c, weight, SBP and DBP, waist circumference, fasting lipids, costs inpatient, outpatient LAGB and diabetes medications and complications, full economic evaluation.	CUA, high. 23/24	Cost/QALY. LAGB is a highly cost-effective treatment in obese patients with T2DM in the UK setting compared with standard medical management
Song 2013 (104), South	LAGB LRYGBP	Severely obese	Hospital adminis-	No surgery.	NA	Yes.	No.	Yes. EQ-5D	Health care	Included. BC not	Model: combined decision tree and Markov, change in	CUA, high.	Cost/QALY. ICER of bariatric surgery compared with conventional treatment was

Korea, (2011 USD), lifetime, DR=5%.	LSG	Korean adults over 30 with BMI 30≤40 (severe obesity for Asian population BMI≥30)	trative, medical charts, survey of bariatric surgeons, National Health Insurance Statistics						system/ third party payer.	included.	mean BMI, utility weights, costs inpatient, outpatient and medications, full economic evaluation.	24/24	US\$1771/QALY, suggesting that bariatric surgery was cost-effective in South Korea.
Wang 2013 (22), United States, USD, lifetime, DR=3%.	LRYGBP ORYGBP LAGB	Individuals eligible for bariatric surgery based on BMI≥35. Reference case 53 year old female BMI=44.	Administrative claims database and published sources.	No surgery.	NA	Yes.	No.	Yes. SF-12 and EQ-5D	Health care system/ third party payer.	Included. BC not included.	Model: decision analytic first 5 years then natural history model, changes in BMI and utility, costs estimated lifetime direct medical costs associated with the three procedures compared with no surgery, full economic evaluation.	CUA high. 23/24	Cost/QALY. \$6600/QALY for LRYGB, \$6200/QALY for LAGB, \$17300/QALY for ORYGB. Bariatric surgery produced additional life expectancy (80-81 years) compared to no surgery (78 years).
Weiner 2013 (74), United States (2005 USD), 6 years.	LAGB, LGBP, OGBP, other restrictive and unknown.	Patients who underwent bariatric surgery, age≥18 years, 1:1 matched.	Health insurance plans.	No surgery.	29820.	Yes.	No.	No.	Not stated.	Included. BC not included.	Retrospective, observational, costs medical and pharmacy claims data, partial economic evaluation.	CCA high. 95%	Changes in mean costs. Regression adjusted ratios. Total costs were greater in the bariatric surgery group during the second and third years following surgery but were similar in later years. Bariatric surgery group's prescription and office visit costs were lower and their inpatient costs were higher. Surgical group costs years 1 to 6 Y1 \$8905 (18 814), Y2 \$9908 (19 273), Y3 \$9211 (19 263), Y4 \$9051 (19 520), Y5 \$9386 (21 137), Y6 \$9259 (26 909).
Castilla 2014 (21), Spain, (2012 EURO), lifetime, DR=3%.	GBP	Patients who underwent bariatric surgery age 18-55 years.	Spanish NHS, published sources.	No surgery.	79.	Yes.	No.	Yes. SF-36 EQ-5D OP MA II	Health care system/ third party payer.	Not included. BC not included.	Model: discrete event simulation, change in utility, costs direct medical costs from Spanish NHS, full economic evaluation.	CUA, high. 22/24	Surgery group gained 5.63 QALYs. Lifetime savings €13944. The total cost of the intervention branch is close to half the cost of the non-intervention branch (€17431 vs €31425).
Bairdain 2015 (76), United States, USD, 7 years, DR=3%.	LRYGBP	Severely obese adolescents who underwent	Children's hospital database.	No surgery.	11.	Yes.	No.	Yes. EQ-5D	Health care system/ third party	Not included. BC not included.	Model: Markov, costs direct medical preoperative, perioperative and postoperative (clinic and ancillary charges), full	CUA, medium. 16/24	Cost/QALY at year 7 \$36570/QALY. At a WTP threshold of \$100000/QALY, bariatric surgery was not cost effective in the first three years, but became cost-effective after three years (\$80065/QALY in year 4 and

		bariatric surgery.							payer.		economic evaluation.		\$36570/QALY in year 7).
Borisenko 2015 (24), Sweden, (2012 EURO), lifetime, DR=3%.	GBP, SG, GB.		Scanadan-avian obesity surgery registry and published sources.	No surgery.	NA	Yes.	No.	Yes. EQ-5D	Health care system/ third party payer.	Included. BC included.	Model: Markov, BMI reduction, CVD, T2DM, complications, utility, costs of surgery with and without complications, annual cost T2DM and CVD (e.g. stroke, MI, TIA), full economic evaluation.	CUA, high. 23/24	Over a lifetime surgery led to savings of €8408 and generated an additional 0.8 LY and 4.1 QALYs per patient. Base-case bariatric surgery cost saving. All four specified diabetic cohorts were cost saving (moderately, severely, morbidly and super obese). Time delay in surgery led to significant losses of clinical benefits (in the range of 0-0.6 LY and 0.2-1.2 QALYs). Losses of clinical benefits higher in males and diabetic patients.
Czernichow 2015 (98), France, EURO, 4 years.	GB, 62.5%, GBP, SG.	Obese patients who had undergone primary bariatric surgery.	National claims insurance database.	Before and after.	350.	Yes.	No.	Yes.	Health care system/ third party payer (stated societal)	Included. BC not included.	Retrospective, observational, costs direct costs. All items of health care consumption eligible for reimbursement and associated costs were assessed for each study period at current prices, partial economic evaluation.	CCA, high. 95%	Annual total direct cost per patient before and after bariatric surgery. Annual per capita reimbursed health expenses evolved from €2633 (±3124) year (T-2) to €3755 (±5037) year (T+2) with differences according to the type of surgery. Most items of medical consumption started to decrease in T+2.
Keating 2015 (78), Sweden, (2013 USD), 15 years.	GB, GBP, VBG.	SOS cohort: Age 37-60 years, men BMI ≥38, women BMI ≥34. Stratified for baseline glucose status.	National prescribed drug register and questionnaires. National patient register (inpatient and outpatient).	CT.	4030 patients 2836 euglycemic 591 pre-diabetes 603 diabetes	Yes.	No.	No.	Not stated.	Included. BC not included.	SOS study, baseline glucose status, costs inpatient, non-primary outpatient and medications, partial economic evaluation.	CCA, high. 100%	Adjusted mean differences for 15 year aggregated drug, outpatient, inpatient, and total healthcare costs. Drug costs were lower in the surgery group for prediabetes (\$10194 vs \$13186; -\$3329 [-5722 to -937]; p=0.007) and diabetes (\$14346 vs \$19511; -\$5487 [-7925 to -3049]; p<0.0001) subgroups than in the CT group. Total healthcare costs were higher for patients with euglycaemia or prediabetes in the surgery group than in the CT group, but we detected no difference between the surgery and CT groups for patients with diabetes.
Warren 2015 (75), United States, USD, 10 years.	All types	Obese T2DM eligible for bariatric surgery and control group T2DM	American Diabetic Association estimates	No surgery.	Surgery eligible group 1000 (surgery 200, no surgery 800) control	Yes.	Yes.	No.	Not stated	Not included. BC not included.	Retrospective, observational, resolution of T2DM, costs direct costs (inpatient and outpatient medical costs) included, indirect costs reduced work productivity and mortality, partial economic evaluation.	CCA, medium. 75%	Total, direct and indirect costs of bariatric surgery. The projected annual costs of T2DM per person is between \$1700 and \$2100. Considering only the direct medical costs of T2DM, the 10 year aggregate cost savings compared with the control group is \$2.7 million/1000 patients; the total (direct and indirect) cost savings is \$5.4 million/1000 patients.

Table 3A: Characteristics of cost-effectiveness and cost-utility studies that investigated people with diabetes who underwent bariatric surgery versus conventional treatment

Reference/currency study population	DR	Cost of the procedure	Economic metric (cost- effectiveness studies – base case)	Economic metric (cost-utility studies base case)	Sensitivity analyses
Anselmino 2009 (99), EURO. Study population: AGB and GBP for BMI ≥ 35 and T2DM	3.5%	Base case input - average cost per patient: GBP: Austria: €6,361; Italy: €7,831; Spain: €8,344. AGB: Austria: €4,785; Italy: €7,759; Spain: €5,995.	GBP: Austria: €740/ T2DM free year; Italy: €637/ T2DM free year; Spain: €1,362/ T2DM free year. AGB: €T2DM free year: Austria: €1,201; Italy: € 452;Spain: €611.	GBP: Austria: €740/QALY gained; Italy: €637/gained; Spain: €1,362/gained. AGB: Austria: €1,201/QALY gained; Italy: €452/QALY gained; Spain: €611/QALY gained. Base case: \$21,973/QALY gained.	Worst case AGB remains cost-saving, GBP breakeven in Austria, Both procedures breakeven in Italy, Both cost- effective in Spain with accepted cost-effectiveness threshold of €30,000/QALY gained.
Ikramuddin 2009 (55), (2007 USD). Study population: RYGBP Mean BMI 48.4 and DM.	3%	Base case input: cost of initial surgery and follow-up: \$24,289. Major reoperation (early) \$38,960, moderate reoperation (early) \$23,851, major reoperation (late) \$42,896, moderate reoperation (late) \$14,736, any complicated weighted average \$14,663.	Base case: \$29,676/life-year gained.	Base case: \$21,973/QALY gained.	Reduced effects on A1C, exclusion of lipid effects, lower and higher DR (0 and 6%) and lower costs of treatment. ICERs remained under \$50,000/QALY gained WTP threshold in most cases. Only when time horizon greatly reduced and QoL impact of increased BMI was excluded ICERs exceeded the threshold. No.
Keating 2009 (85) (2006 AUD). Study population: RCT LAGB and CT BMI >300 recently diagnosed T2DM.	NA	Mean cost per patient over trial period: Cost of LAGB surgery (private hospital): \$8,527. Mitigation of surgical complications (lap-band removal, revisions, port infection) \$866.	AUD\$16,000/additional case of T2DM remitted. USD\$11,840/additional case of T2DM remitted.	NA	
Keating 2009 (86), Australia, (2006 AUD). Study population: LAGB with CT BMI >300 recently diagnosed T2DM.	3%	Cost of the procedure based on Keating 2009 within trial costs (85). Complications unit cost: gastric prolapse \$5,758; band erosion \$14,691; port infection \$2,695; band removal \$5,134.	Cost/life year gained Dominant	Cost/QALY gained Dominant	Worst-case scenarios for the intervention effect and the annual cost of treating T2DM shifted the economic status of surgical therapy from dominant to cost-effective \$39,700/QALY gained and \$13,400/QALY gained respectively.
Hoerger 2010 (56), United States, (2005 USD). Study population: LAGB and GBP to CT severely obese with newly diagnosed DM and severely obese with established DM.	3%	Surgery and first year of costs: GBP \$23,871 (\$6612 – \$55261); LAGB \$15169 (\$2857 – \$30186).	NA	Patients with newly established diabetes: GBP \$7,000/QALY gained; LAGB: \$11,000/QALY gained Patients with established diabetes: GBP: \$12,000/QALY gained; LAGB: \$13,000/QALY gained. £3,602/QALY gained.	Varying surgery costs had a larger impact on GBP than the LAGB ICERs. Varying follow-up costs had a bigger impact on the LAGB than GBP cost-effectiveness ratios. Varying change in BMI from surgery had very little effect but varying the direct QoL improvement per unit of BMI loss from 0.017 to 0 had the biggest impact on cost-effectiveness ratios. All cost-effectiveness ratios were <\$40,000/QALY.
Pollock 2013 (93), United Kingdom, (2010 BPD). Study population: LAGB severely obese with DM for mean 1 year SD standard deviation 4 months.	3.5%	Total mean (standard deviation) direct costs of LAGB surgery base case including inpatient, outpatient, costs of complications, revision and reversal: £23,562 (£22,754 – £24,496).	NA		One-way sensitivity analyses DR 0 and 6%, time horizon, unit costs, HbA1c, SBP and BMI benefits base case was broadly insensitive. Worst case scenario revealed a mean outcome that would not be considered cost-effective at WTP threshold of £20,000/QALY Worst case revealed £36,377/QALY gained. Conversely best case revealed dominance.
Borisenko 2015 (24), Sweden, (2012 EURO). Study pop: 16 cohorts of 41 year old	3%	Cost of bariatric surgery without complications €4,915 (39 – 5,898); cost of bariatric surgery with complications €5,766 (4,613 – 6,919).	NA	Bariatric surgery is cost saving in all 4 pre-specified diabetic cohorts (moderately, severely, morbidly and	One-way sensitivity analysis for all cohorts showed that four parameters can affect the cost saving effect of surgery (1) the magnitude of the effect of surgery, (2)

non-smoking males and females with BMI group and T2DM. Results on other severe obesity multiple cohorts also considered.

super-obese).

start age (better to operate patients when they are younger), (3) BMI (better to operate when BMI is lower), and (4) inclusion of an annual visit to a surgeon during the follow-up program from year three and onwards. Change of cost variables with 50 % variations did not influence the cost saving effect of surgery. The most sensitive parameter from cost variables was the annual cost of type 2 diabetes.

Key: AGB = adjustable gastric band; British Pound = BPD; DM = diabetes mellitus; DR = discount rate; EURO = Euro; GBP = gastric bypass; ICER = incremental cost-effectiveness ratio; LAGB = laparoscopic adjustable gastric band; LRYGBP = laparoscopic Roux-en-Y gastric bypass; LSG = laparoscopic sleeve gastrectomy; QALY = quality-adjusted life-years; RYGBP = Roux-en-Y gastric bypass; SG = sleeve gastrectomy; T2DM = type 2 diabetes mellitus; WTP = willingness to pay

Table 3B: Characteristics of cost-effectiveness and cost-utility studies that investigated people with severe/super-obesity who underwent bariatric surgery versus conventional treatment

Reference/currency study population	DR	Cost of the procedure	Economic metric (cost- effectiveness studies – base case)	Economic metric (cost-utility studies base case)	Sensitivity analyses
Campbell 2010 (26), United States, (2006 USD). Study population: BMI ≥ 40 kg/m ² and BMI ≥ 35 kg/m ² with comorbidities who underwent LAGB and LRYGBP versus no treatment.	3%	Cost of initial surgery and follow-up LAGB \$15,465; LRYGB \$23,157. Cost of early and late major and minor reoperations for both procedures range \$426 to \$41,708.	Aggregate patient population age 40 yrs: LAGB \$9,300/life years saved; LRYGB \$10,200/life years saved Super-obesity BMI >50 kg/m ² : female both LAGB and LRYGB dominating; male LAGB \$600/life-years saved; LRYGB \$1,700/life-years saved. NA	Aggregate patient population age 40 yrs: LAGB \$5,400/QALY gained; LRYGB \$5,600/QALY gained Super-obesity BMI >50 kg/m ² : female both LAGB and LRYGB dominating; male LAGB \$400/QALY gained; LRYGB \$1,100/QALY gained. 2 year time horizon \$48,622/QALY gained; lifetime time horizon \$1,425/QALY gained.	Alternative sources of efficacy estimates, patients assumed to regain half their cumulative BMI lost after 5 years over the following 5 year period. Multiple one way sensitivity analyses then conducted to changes in efficacy, rates of adverse events and costs. Overall parameter uncertainty tested with regard to treatment efficacy, rates of complications, costs and utilities. Results robust to reasonable variation in model parameters. Sensitivity analysis for age, sex, race, pre-surgical BMI, diabetes status and type of surgical procedure. Bariatric surgery was cost-effective under most scenarios, but less cost-effective in men, white patients, less obese patients, and when performed as an open procedure.
McEwen 2010 (59), United States, USD. Study population: Mean BMI 51 kg/m ² with co-morbidities LRYGBP and ORYGBP Chang 2011 (10), United States, (2010 USD). Study population: severely obese with obesity related diseases and without obesity related diseases who underwent bariatric surgery.	3% 3%	Average cost for LRYGBP \$10393; average cost for ORYGBP \$11705. Average cost of bariatric surgery \$26,315. Cost of surgical complications \$1,083, cost of early reoperation \$30,074, cost of perioperative death \$46,782.	Obesity related diseases for BMI 35 - 40 kg/m ² : \$6,468/life-year saved; without obesity related disease for BMI 35 - 40 kg/m ² \$13,249/life-year saved.	Obesity related diseases for BMI 35-40 kg/m ² : \$2,413/QALY gained; without obesity related disease for BMI 35-40 kg/m ² \$3,872/QALY gained. Obesity related diseases for BMI ≥ 50 kg/m ² cost-saving; without obesity related disease for BMI ≥ 50 kg/m ² \$1,904/QALY gained. All surgical procedures showed strong dominance.	Direct medical costs for the base-case were derived from one published study. Varying the cost data with data from other published studies yielded changes from base-case. This sensitivity analyses was only reported for people with obesity-related comorbidities. Cost data from one study revealed cost-saving for all incremental cost-effectiveness ratios. Cost data from another study revealed similar results for BMI 35-40 kg/m ² and higher pre-surgery BMIs revealed cost-saving.
Maklin 2011 (109), Finland, (2010 EURO). Study population: BMI at baseline 47 kg/m ² (range: 38-59 kg/m ²), age 43 years, men 35% (range 9-50), LAGB (2%), GBP (68%), SG(30%).	3%	Average costs of procedures: gastric bypass €14,672; SG €14,752; LAGB €13,210.	NA	NA	Surgery remained dominant when the parameter values for mortality, probability for reoperation, abdominoplasty or co-morbidities, EWL or weight gain after surgery were varied. Increasing the costs of surgery did not remove the dominance. Worst case scenario was evaluated using the most pessimistic parameter values on effectiveness and costs of bariatric surgery. Dominance was also not removed in the worst case scenario. Only variation in BMI at baseline seemed to have an effect on results. Strong dominance of bariatric surgery if BMI set at 38 kg/m ² .
Michaud 2012 (20), United States, (2010 USD). Study population: a) current eligibility: BMI > 40 kg/m ² , or BMI 35-40 with qualifying	3%	Bariatric surgery (focus on RYGBP) total economic cost which includes treatment cost, additional medical expenditures, deadweight loss minus additional earnings: \$12,666.	Current eligibility: \$8,171/life years gained. Extended eligibility: \$10,579/life-years gained.	NA	For the current eligibility population variation in the effectiveness of bariatric surgery, lowering effectiveness by 10% cuts life expectancy gains by 0.55 years and cost/life years increases \$16,405/life-years. Changing the assumption of permanent weight loss to 50% weight

comorbidities; and (b) extended eligibility: BMI > 35 kg/m ² and BMI 30-35 kg/m ² with qualifying comorbidities RYGBP. Faria 2013 (101), Global/Portugal, EURO Study population: severely obese with obesity-related diseases and without obesity-related diseases.	3%	Expected cost LAGB €41,056 and GBP €29,254.	NA	Compared with the best medical management , in the global population of patients with a BMI≥35 kg/m ² , GBP renders 1.9 extra QALYs and saves on average €13,244 per patient	regain cost-effectiveness remains low \$12,318/life-year. The results for bariatric surgery appear to be robust to variation in the effectiveness of treatment.
Lee (89), 2013, Australia, (2003 AUD). Study population: LAGB. BMI>35 kg/m ² and BMI >40 kg/m ² .	3%	Cost of initial LAGB surgery cost/person \$11,290.	BMI >40 kg/m ² dominant (95%CI: dominant – \$588). BMI>35 kg/m ² \$2,154/DALY averted (95%CI: dominant - \$6,033).	NA	Stratified for patient subgroups based on age, BMI, T2DM and absence of co-morbidities. Younger patients <40 years cost saving. T2DM dominance of GBP. Patients with the most benefit are those in the intermediate weight group BMI 40 50 kg/m ² . Patients with BMI 30-35 kg/m ² GBP cost effective €13,071/QALY gained. For the global population GBP is cost-saving from 8 years onwards. Altered DR to 0 and 6 %. Increased annual probability for each complication by order of one magnitude. Tested the stable weight loss assumption. Uncertainty analyses to assess the level of parameter uncertainty. The largest observed changes to base case analyses occurred after excluding cost offsets; and increasing the rates of maintenance and complication by order of magnitude results still fell below the WTP threshold \$50,000/DALY.
Song 2013 (104), South Korea, (2011 USD). Study population: Asian population severely obese 30 - <40 kg/m ² in South Korea.	5%	Cost of initial procedure: LAGB \$7,042; LRYGB \$13,000 and LSG \$9,511.	NA	\$1,771/QALY gained	Sensitivity analyses altered discount rates (0% and 3%), costs (two-way), utility weights, time horizon. Bariatric surgery was dominant with 0% and 3% discount rates however when time horizon reduced by 15 years showed the largest change to \$17,639/QALY gained.
Wang 2013 (22), United States, USD. Study population: Average individual undergoing bariatric surgery 53 year old female BMI 44 kg/m ² .	3%	Total cost < 31 days: LRYGBP \$16,691; ORYGBP \$20,675; LAGB \$14,159	NA	LRYGBP \$6,000/QALY gained; ORYGBP \$17,300/QALY gained; LAGB \$6,200/QALY gained.	Results were sensitive to alternative weight change scenarios. For full weight regain 15 years after the procedure LRYGBP \$24,100/QALY gained; ORYGBP \$59,500/QALY gained; LAGB \$26,700/QALY gained. One way sensitivity analysis showed that parameters with the largest impact were BMI at baseline, age at the time of procedure and gender. ICERs higher with men. LAGB cost-saving at baseline BMI of 54 and above. The ICER estimates for bariatric surgery appear to be cost-effective under most modelled scenarios
Castilla 2014 (21), Spain, (2012 EURO). Study population: Average BMI 50.7 kg/m ² (range: 36.6 – 76.3)	3%	Cost of GBP €8,240.		Dominates	Analysis of covariance showed that T2DM-related parameters account for most of the variability in incremental cost (approximately 25%). Only the variability of the base utility associated with the lowest BMI had a noteworthy impact on the variability of the incremental effectiveness of the intervention (8%). Results at different time horizons 5 years: dominates; 10 years €4,045/QALY gained; 15 years €90/QALY gained; 20 year dominates.

Key: AGB = adjustable gastric band; BPD = British Pound; DM = diabetes mellitus; DR = discount rate; EURO = Euro; GBP = gastric bypass; ICER = incremental cost-effectiveness ratio; LAGB = laparoscopic adjustable gastric band; LRYGBP = laparoscopic Roux-en-Y gastric bypass; LSG = laparoscopic sleeve gastrectomy; QALY = quality-adjusted life-years; RYGBP = Roux-en-Y gastric bypass; SG = sleeve gastrectomy; T2DM = type 2 diabetes mellitus; WTP = willingness to pay

Table 4: Generally accepted cost effectiveness (willingness to pay) thresholds for United States, United Kingdom, Sweden, Canada and Australia.

Country	Cost-effectiveness threshold	Comment
United States (USD)	\$50,000 - \$100,000/QALY gained (144)	The United States has legislated against the explicit use of cost-QALY thresholds. Recent evidence suggests that if one had to select a single threshold outside the context of an explicit resource constraint or opportunity cost, use either \$100,000 or \$150,000.(144)
United Kingdom (BPD)	£20,000/QALY gained and £20,000 – £30,000/QALY gained	The National Institute for Health and Care Excellence has never identified an incremental cost-effectiveness ratio above which interventions should not be recommended and below which they should. However, in general, interventions with an incremental cost-effectiveness ratio of less than £20,000 per QALY gained are considered to be cost effective. As the incremental cost-effectiveness ratio of an intervention increases in the £20,000 to £30,000 range, an advisory body's judgement about its acceptability as an effective use of National Health Service resources should make explicit reference to relevant factors outlined by the Institute (147).
Sweden (EURO)	€57,000/QALY gained	Relevant government authorities have suggested a threshold of SEK 500,000 (approximately €57,000) (143).
Canada (CAD)	\$20,000 – \$100,000/QALY gained (148) \$124,000/QALY gained (149)	Health-care programmes, which cost less than US\$12,800 (CAN\$20,000) per QALY are highly cost effective, but weak if the ratio exceeds US\$64,000 (CAN\$100,000) (148).
Australia (AUD)	\$50,000/QALY gained	Pharmaceutical Benefits Advisory Committee was unlikely to recommend a drug for listing if the incremental cost-effectiveness ratio (cost per life-year) exceeded AUD \$76,000 (150).

Figure Legend

Figure 1: Results of search strategy based on PRISMA methodology.

Figure 2A: Methodological quality of partial economic evaluations rated against the CHEERS checklist: low ($< 60\%$), medium ($60\% - 80\%$) and high ($> 80\%$).

Figure 2B: Methodological quality of full economic evaluations rated against the CHEERS checklist: low (≤ 14 points), medium ($15 - 19$ points) and high ($20 - 24$ points).

OBR_12424_F1.tif

OBR_12424_F2a.tif

OBR_12424_F2b.tif

Minerva Access is the Institutional Repository of The University of Melbourne

Author/s:

Campbell, JA;Venn, A;Neil, A;Hensher, M;Sharman, M;Palmer, AJ

Title:

Diverse approaches to the health economic evaluation of bariatric surgery: a comprehensive systematic review

Date:

2016-09-01

Citation:

Campbell, J. A., Venn, A., Neil, A., Hensher, M., Sharman, M. & Palmer, A. J. (2016). Diverse approaches to the health economic evaluation of bariatric surgery: a comprehensive systematic review. OBESITY REVIEWS, 17 (9), pp.850-894. <https://doi.org/10.1111/obr.12424>.

Persistent Link:

<http://hdl.handle.net/11343/291939>