Obesity Surgery, ***16****, 1488-1503*

Cost-Effectiveness and Budget Impact of Obesity Surgery in Patients With Type-2 Diabetes in Three European Countries

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Background: We aimed to establish a payer-perspective cost-effectiveness and budget impact (BI) model of adjustable gastric banding (AGB) and gastric bypass (GBP) vs conventional treatment (CT) in patients with BMI ≥35 kg/m² and type-2 diabetes T2DM, in Germany, UK and France.

Methods: Clinical evidence was obtained from literature and patient-reported EQ-5D scores given BMI and T2DM status from HODaR. Resource utilization data in AGB, GBP and CT were obtained from quoted publications so as to reflect practice in 2005. CT in each country was based on descriptions in HTA reports or based on co-authors' experience of current practice. Unit costs were obtained from published sources when available, or from co-authors' institutions. A deterministic algorithm with cost and utility discounting, enabled selection of inputs independently throughout the time scope for each of the 3 treatments, and included mean BMI, amounts of resources and unit costs.

Results: The base case time-scope was 5 years, and the annual discount rate for utilities and costs was 3.5%. Compared to CT, GBP yielded +80.8 kg/m².years, +2.6 T2DM-free-years and +1.34 QALYs. AGB yielded +57.8 kg/m².years, +2.5 T2DM-free-years and +1.03 QALYs. In Germany and France, both GBP and AGB yielded a cost decrease, and were thus dominant in terms of ICER compared to CT. In the UK, GBP and AGB yielded a cost increase, but were cost-effective.

Conclusion: In patients with T2DM and BMI ≥35 kg/m², AGB and GBP are effective at 5-year follow-up in cost-saving in Germany and France, and are cost-effective in the UK with a moderate BI vs CT.

Key words: Morbid obesity, obesity surgery, gastric bypass, adjustable gastric banding, cost-effectiveness, budget impact, EQ-5D utility, diabetes, survival

Presented at the 4th International Alpine Obesity Surgery Expert Meeting, Saalfelden, Austria, March 14, 2006.

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Abbreviations:
ABG, Adjustable gastric banding
GBP, Gastric bypass
CT, Conventional treatment
T2DM, Type 2 diabetes mellitus
BI, Budget impact
HODaR, Health Outcomes Data Repository
HTA, Health Technology Assessment
QALYs, Quality adjusted life years
EQ-5D, EuroQol 3-level 5-dimensional
ICER, Incremental cost-effectiveness ratio
TTO, Time trade-off

Introduction

Type-2 diabetes mellitus (T2DM) is a frequent co-morbidity of obesity.[1-17] Consensus conferences and guidelines establish that bariatric surgery can be proposed to adults with a body mass index (BMI) ≥35 kg/m² and T2DM, when at least 1 year of well conducted medical treatment has failed. Evidence shows that both bariatric operations (adjustable gastric banding, AGB, and gastric bypass, GBP) are safe and able to produce significant BMI reduction sustained at 5-year follow-up, as well as frequent remission of T2DM.[19] The increasing prevalence of patients who meet clinical eligibility criteria established in clinical practice guidelines is a concern to health-care policy-makers and payers across Europe, because of its impact on the organization and cost of surgical services.

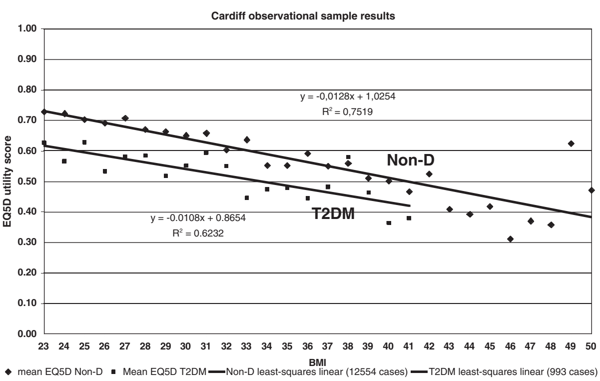
Bariatric surgeons in Germany, UK and France have collaborated on the development of a series of programmable models based on a common core, that address in an intuitive manner the following questions: *How much clinical benefit can be gained if a given number of patients are operated by GBP, AGB or kept on conventional treatment? What will it cost?*

What is the value for money if patients are operated rather than treated conventionally? How does the proportion of patients with T2DM influence the answers?

Methods

Model Inputs: Baseline prevalence of T2DM in the target population was by definition 100%. Clinical outcome variables of interest were annual BMI variation, annual T2DM prevalence variation associated to the use of anti-diabetic drugs, and treatment complications up to 5 years after bariatric surgery (GBP or AGB) or conventional treatment (CT). Clinical evidence was obtained from publications quoted in Health Technology Assessment (HTA) reports issued by NICE, ANAES, ASERNIP-S, SBU and the DGA.[20-25] Randomized clinical trials and non-comparative prospective series of consecutive patients treated by GBP or AGB that may have been published after these HTA reports, were also searched for in PubMed in June 2005.

Patients' self-rating of their current health-related quality of life according to their BMI and their T2DM status, was estimated from a database of 13,547 individuals provided by the HODaR Cardiff Research Consortium (Figure 1).[26-28] HODaR database societal-perspective utility scores were calculated for each patient using their answer to the *EuroQol 3-level 5-dimensional health outcome EQ-5D questionnaire*. The EQ-5D, analyzed according to the algorithm derived from the *Time Trade-Off (TTO)* data of the York Survey, has 243 theoretically possible health states, with a score of 1.0 representing the best possible patient perception of health-related quality of life (perfect or full health),



Source: HODaR, Cardiff (References 26-28)

Figure 1. Relationship between EQ-5D score – BMI – T2DM – Sample source data.

where 0 represents an extremely poor quality of life perception equivalent to death. As health status perception degrades, EQ-5D score declines towards 0. Health status perceived as worse than death corresponds to a negative EQ-5D score (the worse score according to the TTO is -0.594).[29-33]

A comprehensive list of health-care resources necessary for preoperative assessment, laparoscopic GBP and AGB surgical operations, follow-up and the treatment of complications up to 5 years after surgery, was established in Germany, UK and France by the authors. Resource items for GBP and AGB included the amounts of human resources (surgeons, physicians, nurses, nutritionists), imaging and laboratory tests, operating-room overhead, post-surgical recovery room, hospital stay, consultations, re-operations in case of complications, implants, etc. For each of these resource items, the range of amounts was described (i.e. the lowest, most common or average, and highest number of units). As regards procedure duration, length-of-stay and frequency of complications, the ranges and averages reported in the literature served as a reference base, but authors' expert-opinion was used instead of published values when literature data appeared obsolete compared to practice in 2005. Ranges of unit costs for each resource item were collected using applicable national tariffs, registries, publications and interviews when no other source was available. Ranges of resource amounts and ranges of unit costs were multiplied, added up and discounted to yield the net present cost of treatment. The authors of this article confirmed the most plausible combination of resources and unit costs as applicable in their institutions. Literature-based averages and expert opinions enabled establishment of a "base case" for the cost of AGB and GBP. A similar cost analysis process was conducted for the conventional treatment of obesity after failure of at least one prior year of well-conducted medical treatment; however, as no standard was identified in any of the three countries, the base case was defined, according to HTA reports or authors' opinion, as either as annual follow-up watchful waiting or continuation of a second year of medically guided dieting. The annual cost of treating T2DM in the three countries was obtained from the CODE-2 survey published results.[34] The average annual cost reported for each resource in the CODE-2 publication was used to define the model's base case. This included resources used for the control of glycemia and for the treatment of T2DM complications.

Model Assumptions: General assumptions were required to establish this cost-effectiveness model, independently of the base case: a 5-year time-scope is relevant to compare conventional treatment and bariatric surgery. The model applies if at least one prior year of well conducted medical treatment has failed. A BMI reduction or increase of 1 kg/m^2 is considered to have the same utility whatever the starting BMI. Treatment effectiveness on excess weight is proportional to the magnitude of BMI variation (measured in kg/m^2) and to the duration of BMI variation, so that magnitude and duration should be combined in a single variable measured in *kg/m^2 x year* (i.e. *BMI.years*). Treatment effectiveness on T2DM is proportional to both the number of patients in whom remission is observed and the duration of remission, so annual residual T2DM prevalence and duration are combined in a single variable measured in *T2DM-free Life Years*. The combined effectiveness in terms of BMI reduction and T2DM remission is suitably summarized through EQ-5D patient answers, where EQ-5D score is a linear function of BMI and presence of T2DM. Patients with a higher BMI report a lower score than patients with low BMI (as long as it is more than underweight), and patients with T2DM report a lower score than patients without (Figure 1). Treatment utility is proportional to both the increase in EQ-5D utility score and to the duration of the increase, so these two components are combined in a single variable measured in *Quality-Adjusted Life Years (QALYs)*. The average patient's EQ-5D score varies along this linear relationship over time during the 5-year scope, depending on BMI variations and remission or development of T2DM, so that knowledge of BMI and T2DM status at any time during the 5-scope suffices to determine the patient's EQ-5D score (Figure 2). Cumulative costs and *QALYs* over years must both be discounted in order to obtain a consistent net present value that reflects the principle that 1£ or € now are worth more than in the future, and that living one healthy year now is worth more than one future healthy year. The discount rate can be set independently for each parameter. Clinical outcomes measurements used in the model are the mean annual values and are considered to apply over a full 1-year period.

Algorithm Design and Implementation: A deterministic linear algorithm was programmed in Microsoft Excel™.

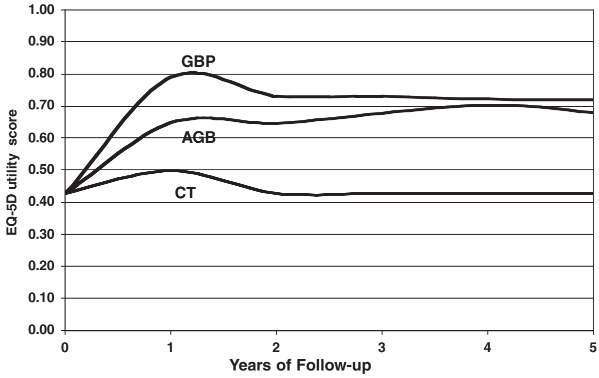


Figure 2. Base case inputs - longitudinal EQ-5D score per BMI & T2DM status – Output QALYs.

Model Inputs: Fifteen main input variables were defined as independently programmable by model users. Eight of those were actually defined as groups of finer-detail variables that are also independently programmable. Some input variables are allowed to be programmed only within upper and lower boundaries found in the quoted publications or based on authors' experience. Effectiveness of each treatment in terms of BMI and T2DM prevalence was selected at each follow-up year of the selected time-scope (Figure 3 and Figure 4). Annual marginal effectiveness was defined as the absolute difference in mean BMI at each year of follow-up compared to baseline and multiplied by a 1-year duration to yield a number of *kg/m^2 x years* ($BMI.years_{marginal\ year\ y} = [BMI_{year\ y} - BMI_{baseline}]$ *x 1 year*). Cumulative effectiveness at y years of follow-up is the sum of annual marginal effectiveness values ($BMI.years_{cumulative\ year\ y} = 1\_y[BMI.years_{marginal\ year\ y}]$). Effectiveness of treatment is proportional to the cumulative *kg/m^2 x years* lost over the scope. Effectiveness of each treatment on T2DM was defined at each follow-up year. Annual marginal effectiveness was defined as the average number of years free of T2DM gained by patients who presented this complication at baseline, over each follow-up year. Reviewed publications provide prevalence of T2DM at baseline and each follow-up year *y*, thus enabling estimation of relative prevalence variations of T2DM. The average marginal T2DM-free-year gained at year y by patients who had T2DM at baseline is ($[1-(\%T2DM_{year\ y} / \%T2DM_{baseline})]$ *x 1 year*). The average cumulative T2DM-free-year gained at year *y* by these patients is ($T2DM\text{-}free\text{-}years_{cumulative\ year}\ y =$

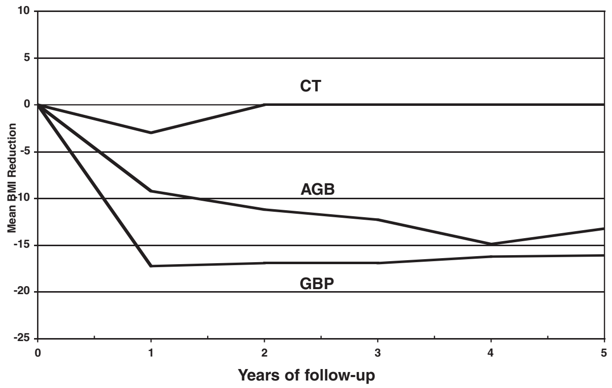


Figure 3. Input panel - Effectiveness – BMI absolute variation compared to baseline.

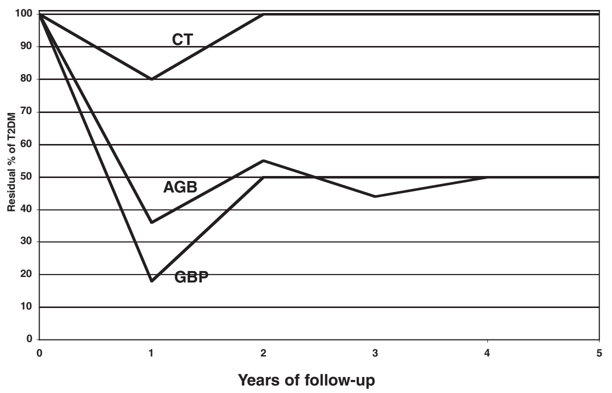


Figure 4. Input panel - Effectiveness – T2DM relative prevalence variation compared to baseline.

1_y([1-(%T2DM$_{year\ y}$ / %T2DM$_{baseline}$)] x 1 year). Effectiveness of treatment is proportional to the cumulative *T2DM-free-years* gained over the scope.

The cost of conventional treatment in each country over the selected time-scope was based on the identification of the main cost-driving health-care resources during prior research. The number of units of each cost-driver and the corresponding price units were selected within defined boundaries reflecting national possibilities. Each marginal annual cost was calculated as a linear equation of the various cost inputs. Marginal annual costs over the selected time scope were added up and discounted with the selected annual discount rate.

The cost of GBP or AGB in each country over the selected time-scope was calculated according to the same approach as conventional treatment but it also included the cost of complications. Given that publications do not provide sufficiently homogeneous data about the timing of the various complications, the assumption was made that the average complication cost should be counted during year one, thus resulting in a conservatively high impact of the cost estimation of bariatric surgery. In Germany, the G-DRG tariff applicable in 2005 was applied as the cost of the initial admission. In France, the GHS tariff applicable in public hospitals in 2005 was applied as the cost of the initial admission. In the UK, the cost of the initial admission was based on micro-costing.

Model Outputs: Eight output variables were calculated. *QALYs* over the selected time-scope were calculated for each treatment and each follow-up year using annual mean EQ-5D scores. These were calculated as a linear combination of the year's mean BMI and T2DM residual prevalence. The equation of the linear combination was the same for all treatments and used the parameters selected in input. A large cumulative incremental utility indicates greater and/or longer-lasting BMI reduction, and/or indicates greater and/or longer-lasting reduction in T2DM prevalence with one treatment than with the other. Incremental cost over the selected time-scope was calculated using discounted cumulative costs with bariatric surgery and conventional treatment, taking into account the cost of T2DM treatment given the residual prevalence of T2DM. *Budget impact* was defined as the number of patients considered for either bariatric surgery or conventional treatment during 1 year and subsequent follow-up for the remaining time of the selected time-scope, multiplied by the mean incremental cost between surgery and conventional treatment over the time-scope. This number represents the overall cost difference for this group of patients over the selected time-scope.

Base Case Inputs: A *base case* was defined for conventional treatment and for AGB and GBP in each country. Four specific assumptions were required to establish the base case: 1) Conventional treatment, whether watchful waiting or another year of medically guided dieting, in patients who meet eligibility criteria for bariatric surgery, may at best yield a temporary moderate reduction in BMI, with a return to baseline or possibly an overshoot after year 1. After that extra year, conventional treatment consists of annual check-ups with no effect on BMI.[23,35-44] 2) Clinical outcomes reported in quoted publications are representative of outcomes achieved in currently treated average patients who are eligible according to guidelines. 3) The relative prevalence of T2DM increases when mean BMI increases, and decreases when mean BMI decreases. 4) This relationship applies over 5 years, as suggested by some studies. The smallest percentage variation from 1 year to the other reported in the literature was used to define the base case, in order to not overestimate the magnitude of the effect of treatment on T2DM. The pooled resource use reported in the literature was used to define the base case. When the bariatric surgeons who participated in this model considered that published resources no longer reflected current practice in 2005 in their countries, their expert opinion was used instead. Usual resource use in 2005 for initial admission was confirmed by two NHS hospitals. Average G-DRG 2005 tariff in Germany and national GHS 2005 tariff for public hospitals in France, were used to reflect the cost from a payer perspective in these two countries that year.

Base case background parameters (Table 1) were a follow-up scope of 5 years, cost and utility discount rates of 3.5%, and a 1,000 eligible patient group considered to calculate budget impact.[45] Baseline prevalence of T2DM was set at 100% in target-eligible patients with a BMI ≥35 kg/m^2, which reflects the target population of the present case.[17]

Source data concerning the effectiveness of AGB in terms of BMI at year 1 through year 5 and in terms of T2DM prevalence at year 1 through year 3, were derived from 13 publications (Table 2).[46-58] Complication rates requiring rehospitalization or reintervention after AGB included in the treatment cost calculation were derived from these 13 publications (Table 3).

Source data concerning the effectiveness GBP in terms of BMI at year 1 through year 5 and in terms of T2DM prevalence at year 1 through year 3 were derived from 11 publications (Table 2).[59-69] Complication rates requiring rehospitalization or reintervention after GBP included in the treatment cost calculation were derived from two published literature reviews (Table 4).[24,70]

Source data concerning the potential effectiveness of conventional treatment in terms of BMI and T2DM prevalence were those regarded as evidence-based in two literature reviews.[23,25] The base case for these two parameters reflected these source data, taking into account the conservative estimates, i.e. those that would not overestimate improvement. BMI variation up to 5 years after AGB and GBP was directly based on reported results, while the conservative T2DM prevalence variation was extrapolated to year 3 and year 4, based on published data at year 3 based on BMI reduction stability until year 5 and the relationship between these two variables. Base case conventional treatment of obesity was defined for each country as the reasonable alternative to surgery in patients in whom 1 year of well conducted medical treatment had already failed. It was assumed to be continued intensive medical treatment for 1 year, and medical monitoring without intervention was continued during 4 years.

Table 1. Base case input – background parameters

Baseline T2DM prevalence	Annual cost discount rate	Annual utility discount rate	No. of patients considered for treatment
100%	3.5%	3.5%	1,000

Table 2. Source data summary – Effectiveness of conventional treatment, AGB and GBP

Follow-up scope	year 1	year 2	year 3	year 4	year 5
Conventional – BMI reduction (kg/m^2)	2.0	0.0	0.0	0.0	0.0
Conventional – T2DM relative prevalence	20%	0%	0%	0%	0%
AGB – BMI reduction (kg/m^2)	9.2	11.2	12.3	14.9	13.2
	6.6-13.9	9.0-17.9	8.5-19.0	14.9-19.1	12.3-15.0
AGB – T2DM relative prevalence	64%	45%	56%	N.D.	N.D.
GBP – BMI reduction (kg/m^2)	17.7	16.9	16.9	16.2	16.1
	13.0-20.0	13.0-18.0	13.0-18.0	10.0-18.0	8.0-18.0
GBP – T2DM relative prevalence	82%	50%	75%	50%	50%

Table 3. Base case input – AGB complications requiring a rehospitalization or reintervention

Complication	Minimum	Pooled average	Maximum
Band removal	0.00%	2.62%	7.00%
Band removal & conversion to other bariatric surgery or major intervention on digestive tract	0.00%	1.57%	8.37%
Band replacement	0.67%	4.05%	13.40%
Band revision, repair and disconnection	0.00%	1.22%	10.00%
Reintervention on port / connector / tube	0.00%	3.67%	28.00%
Incisional hernia repair, other wall intervention	0.60%	0.34%	29.17%
Other reinterventions with general anesthesia, e.g. adhesion removal	0.34%	0.04%	0.34%
Re-hospitalization for other complications	2.38%	0.04%	2.38%

Table 4. Base case input – GBP complications requiring a rehospitalization or reintervention

Complication	Minimum	Pooled average	Maximum
Reoperation: revision / fistula / perforation / erosion	0.19%	0.7%	0.7%
Reoperation: splenectomy	0.35%	0.35%	0.35%
Reoperation: cholecystectomy	1.44%	1.74%	1.74%
Endoscopic dilation of gastro-jejunal stenosis	0.12%	4.9%	4.9%
Intestinal segmental resection	0.00%	0.00%	0.00%
Abdominal wall: incisional hernia, infection/hematoma	0.38%	0.38%	13.42%
Adhesiolysis/internal hernia/colon stenosis/occlusion	1.33%	3.37%	3.37%
Other complication: pulmonary embolism, ulcer	1.63%	1.63%	4.31%

Regardless of the medical approach of the conventional treatment, the effectiveness was assumed to be minimal. Thus, a small and temporary (1-year) reduction in mean BMI and T2DM prevalence was set consistently with the reviewed literature. Selected input effectiveness values in terms of BMI and T2DM prevalence for all three treatment methods used in the base case are summarized in Table 5.

Selected input cost values for AGB and laparoscopic GBP in the three countries are summarized in Table 6 and Table 7 respectively. Selected input cost values for conventional treatment of morbid obesity used in the base case, are in line with base case assumptions concerning this approach in each country, and are summarized in Table 8. Selected input cost values related to the treatment of T2DM used in the base case, were directly based on CODE-2 source data (Table 9).

The base case parameters of the linear combination that calculates EQ-5D utility scores according to BMI and T2DM result in two strictly parallel regression lines (Figure 4) with one for patients with T2DM and the other for patients without T2DM. These two lines have a common slope that is the weighted average of the slopes of the two empirical lines reported by HODaR (Figure 1) for patients with and without T2DM. This weighted average slope has been obtained by pooling the observations in patients with and without T2DM, which result otherwise in two nearly parallel lines if patients with and without T2DM are not pooled.

Results

Clinical Outcomes: Incremental cumulative effectiveness and utility over the 5-year scope versus conventional treatment was: 80.8 *kg/m².years,* 2.6 *T2DM-free-years* and 1.34 *QALYs* for GBP, and 57.8 *kg/m².years*, 2.5 *T2DM-free.years* and 1.03 *QALYs* for AGB. The details of these results are presented in Table 10.

Costs: Incremental cumulative cost over the 5-year scope compared to conventional treatment was: 5030€ for GBP and -3586€ for AGB in Germany (Table 11); -5877€ for GBP and -4480€ for AGB in France (Table 12); and +£2033 for GBP and +£1984 for AGB in the UK (Table 13). Thus, bariatric surgery in these patients is cost-saving in Germany and France, and is cost-increas-

Table 5. Selected base case input – Effectiveness of conventional treatment, AGB and GBP

Follow-up scope	baseline	year 1	year 2	year 3	year 4	year 5
Conventional – BMI reduction (kg/m^2)	0.0	3.0	0.0	0.0	0.0	0.0
Conventional – T2DM relative prevalence	100%	80%	100%	100%	100%	100%
AGB – BMI reduction (kg/m^2)	0.0	9.2	11.2	12.3	14.9	13.2
AGB – T2DM relative prevalence	100%	36%	55%	44%	50%	50%
GBP – BMI reduction (kg/m^2)	0.0	17.7	16.9	16.9	16.2	16.1
GBP – T2DM relative prevalence	100%	18%	50%	50%	50%	50%

Table 6. Base case input – Cost of AGB – Share funded by statutory payers

Country	Germany		France		United Kingdom	
Health-care resources	units	€/unit	units	€/unit	units	£/unit
Preoperative assessment prior to initial admission						
Preoperative assessment (summary)	1	383.00	1	1103.00	1	610.00
Initial hospital admission for surgery						
Hospital stay (lump sum)	1	4116.00	1	4114.15		
Hospital stay – per diem cost					5	241.00
Surgery – overhead (hours)					1.9	492.00
Implant			1	1119.00	1	1175.00
Annual follow-up – year 1 through 5						
Average annual cost	1.00	277.00	1.00	726.00	1	439.00
Complications						
Average cost per patient	1.00	466.00	1.00	454.00	1	296.00
Preoperative Assessment		**€383.95**		**€716.95**		**£ 610.00**
Initial hospital admission for surgery		**€4116.00**		**€5233.15**		**£ 3314.80**
Total annual follow-up – year 1 through 5		**€277.00**		**€471.90**		**£ 439.00**
Complication costs		**€466.00**		**€454.00**		**£ 296.00**
Cumulative discounted – annual 3.5%		**€6047.77**		**€8318.19**		**£ 6060.18**

– To not underestimate the burden of complication, their cost is discounted as if they occurred at year 1.
– Regulated patient co-payments are deducted from the item costs.
– In Germany, initial hospital cost from a payer perspective is a G-DRG 2005 tariff without implant supplement. In France, it is a GHS 2005 public tariff payment with an implant supplement.

ing in the UK. Incremental cost-effectiveness ratios over the 5-year scope compared to conventional treatment were -3754€/QALY (Table 11), -62.3€/BMI.year, -1920€/T2DM-free.year (Figure 5) for GBP and were -3488€/QALY (Table 11), -62.0€/BMI.year and -1463.7€/T2DM-free.year (Figure 6) for AGB in Germany. They were -4385€/QALY (Table 12), 72.7€/BMI.year, -2243€/T2DM-free-year (Figure 7) for GBP and were -4357€/QALY (Table 12), -77.5€/BMI.year, -1828.5€/T2DM-free.year (Figure 8) for AGB in France. They were +1517£/QALY (Table 13), +25.2£/BMI.year, +776£/T2DM-free.year (Figure 9) for GBP and were +1929£/QALY (Table 13), +34.3£/BMI.year, +810£/T2DM-free-year (Figure 10) for AGB in the UK. Thus, bariatric surgery in these patients is dominant (i.e. more effective and less expensive) over conventional treatment in Germany and France. It can be considered cost-effective in the UK, as it involves an incremental cost of significantly less than £20,000 per incremental quality-adjusted life gained.[45]

Budget Impact: The budget impact over 5 years of treating a cohort of 1,000 in Germany with bariatric surgery instead of conventional treatment is a net saving of 5.03 million € in the case of GBP and 3.59 million € in the case of AGB (Table 11). In

Table 7. Base case input – Cost of Laparoscopic GBP – Share funded by statutory payers

Country	Germany		France		United Kingdom	
Health-care resources	**units**	**€/unit**	**units**	**€/unit**	**units**	**£/unit**
Preoperative assessment prior to initial admission						
Preoperative assessment (summary)	1	167.00	1	1083.00	1.00	610.00
Initial hospital admission for surgery						
Hospital stay (lump sum)	1	4116.00	1	4114.15		
Hospital stay – per diem cost					4.88	235.18
Surgery – overhead (hours)					3.84	186.71
Implant					1	2591.00
Annual follow-up – year 1 through 5						
Average annual cost	1.00	172.48	1.00	830.00	1	312.00
Complications						
Average cost per patient	1.00	292.00	1.00	352.35	1	45.00
Preoperative Assessment		**€167.00**		**€703.95**		**£ 610.00**
Initial hospital admission for surgery		**€4116.00**		**€4114.15**		**£ 4455.64**
Total annual follow-up – year 1 through 5		**€172.48**		**€539.50**		**£ 312.00**
Complication costs		**€292.00**		**€352.35**		**£ 45.00**
Cumulative discounted – annual 3.5%		**€5199.05**		**€7431.47**		**£ 6346.52**

– To not underestimate the burden of complication, their cost is discounted as if they occurred at year 1.
– Regulated patient co-payments are deducted from the item costs.
– In Germany, initial hospital cost from a payer perspective is a G-DRG 2005 tariff without implant supplement. In France, it is a GHS 2005 public tariff payment without an implant supplement.

Table 8. Base case input – Cost of conventional treatment – Share funded by statutory payers

Country	Germany		France		United Kingdom	
Health-care resources	**units**	**€/unit**	**units**	**€/unit**	**units**	**£/unit**
Treatment during year 1						
Admission in institution (days)			30	150.00		
Specialist consultations			6	24.00		
GP consultations	6	6.00			4	14.00
District nurse consultations					2	20.50
Practice nurse consultations					2	5.50
Dietician consultations					2	23.00
Laboratory assessments	2	179.00	2	530.55	1	150.00
Food substitutes (daily meals)	365	2.00	2.00	2.00	56	1.07
Medications (daily dosage)						
Annual follow-up – year 2 through 5						
Admission in institution (days)						
Specialist consultations						
GP consultations	1	6.00	2	24.00	1	14.00
District nurse consultations						
Practice nurse consultations						
Nutritionist consultations						
Laboratory assessments	1	179.00	1	530.55	1	150.00
Food substitutes (daily meals)						
Medications (daily dosage)						
Total year 1		**€1124.00**		**€4863.22**		**£ 363.92**
Total annual follow-up – year 2 through 5		**€185.00**		**€377.86**		**£ 164.92**
Cumulative discounted – annual 3.5%		**€1741.73**		**€6038.08**		**£ 932.92**

– Regulated patient co-payments are deducted from the item costs. 2005 cost basis.

Table 9. Base case input – cost of T2DM – Share funded by statutory payers

Country	Germany		France		United Kingdom	
Health-care resources	**units**	**€/unit**	**units**	**€/unit**	**units**	**£/unit**
Annual care						
Ambulatory care	1	388.00	1	683.00	1	543.00
Anti-diabetic drugs	1	119.00	1	207.00	1	44.00
Other drugs	1	896.00	1	633.00	1	337.00
Hospital care	1	2173.00	1	1540.00	1	500.00
Total annual follow-up - year 1 through 5	**€3576.00**		**€3063.00**		**£ 1424.00**	
Cumulative discounted - annual 3.5%	**€16145.83**		**€13829.61**		**£ 6429.43**	

CODE-2 data.34 Assumption: 100% coverage of diabetic treatment cost in the 3 countries. 1999 cost basis

Table 10. Base case output – Cumulative effectiveness and utility at 5-year follow-up

Gained outcomes	kg/m^2.years	T2DM-free-years	QALYs
Conventional	3.0	0.2	2.0
AGB	60.8	2.7	3.0
GBP	83.8	2.8	3.3
AGB – Conventional	57.8	2.5	1.0
GBP – Conventional	80.8	2.6	1.3

France, it is a net saving of 5.88 million € in the case of GBP and 4.48 million € in the case of AGB (Table 12). In the UK, it is a net cost increase of 2.03 million £ in the case of GBP and 1.98 million £ in the case of AGB (Table 13).

Worse Case Scenario Analysis in Patients with T2DM: This approach was chosen rather than a classical sensitivity analysis. Table 14 provides the details of an outcome scenario in patients with a BMI ≥35 kg/m^2 and T2DM in the three countries, in which AGB and GBP were about 20% less effective in terms of BMI reduction and T2DM remission than is assumed in the literature-supported base case, and conventional treatment was low-cost watchful waiting only with no BMI reduction and no T2DM remission at all. The annual cost of treating T2DM is assumed to be the same as in the base case. In this scenario, in Germany, GBP and AGB remain cost-saving over 5 years and dominate conventional treatment in terms of cost-effectiveness. In France, GBP remains cost-saving over 5 years and dominates conventional treatment in terms of cost-effectiveness, whereas AGB becomes slightly cost-increasing but remains very cost-effective. In the UK, GBP and AGB become a little more cost-increasing but remain cost-effective.

Discussion

Suitability of Decision Models for this Type of Problem: Decision-tree modeling techniques are being used increasingly to understand the value in terms of cost of the treatment of morbid obesity, because many sources of clinical and economic information are necessary to grasp all aspects of the problem at once. Probabilistic and deterministic models have been previously published in the areas of GBP, AGB and conventional treatment.[71-74] Markov or semi-Markov models with probabilistic sensitivity analysis using techniques such as Monte Carlo simulation achieve more accurate results and enable conclusions taking into account the likelihood of the various outcome scenarios. However, deterministic models prove reasonably accurate and more intuitive for stakeholders who have not been trained in probabilistic modeling techniques and would like to use these simulation tools to forecast situations relevant to their own area of responsibilities.

Suitability of the Model Structure Chosen: The question that we address is *how do surgery and continued conventional treatment compare in terms of outcomes, costs and value-for-money in patients in whom conventional treatment has already been proven to fail.*

Table 11. Output: Incremental cost-utility and budget impact in Germany

Follow-up duration	1 year	2 years	3 years	4 years	5 years
GBP vs conventional: baseline BMI ≥35 kg/m² & 100% T2DM prevalence					
cumulative cost/patient GBP (€)	5209	7039	8807	10516	12166
cumulative cost/patient Conventional (€)	3850	7361	10753	14 030	17197
Δ cumulative cost/patient (€)	**1,359**	-322	- 1 9146	-3 514	**-5030**
cumulative utility/patient GBP (QALYs)	0.76	1.44	2.10	2.73	3.34
cumulative utility/patient conventional (QALYs)	0.48	0.88	1.27	1.64	2.00
Δ cumulative utility/patient (QALYs)	**0.28**	0.56	0.84	1.09	**1.34**
ICER over the scope (€/QALY)	4825	-570	-2322	-3213	-3754
Budget impact for 1,000 patients (million €)	+ 1.36	-0.32	-1.95	-3.51	-5.03
AGB vs conventional: baseline BMI ≥35 kg/m² & 100% T2DM prevalence					
cumulative cost/patient AGB (€)	6309	8403	10072	11872	13610
cumulative cost/patient Conventional (€)	3850	7361	10753	14030	17197
Δ cumulative cost/patient (€)	**2459**	1,042	-681	-2158	**-3586**
cumulative utility/patient AGB (QALYs)	0.63	1.23	1.84	2.45	3.03
cumulative utility/patient conventional (QALYs)	0.48	0.88	1.27	1.64	2.00
Δ cumulative utility/patient (QALYs)	**0.14**	0.35	0.57	0.81	**1.03**
ICER over the scope (€/QALY)	16988	2989	-1185	-2648	-3488
Budget impact for 1,000 patients (million €)	+2.46	+1.04	-0.68	-2.16	-3.59

Table 12. Output: Incremental cost-utility and budget impact in France

Follow-up duration	1 year	2 years	3 years	4 years	5 years
GBP vs conventional: baseline BMI ≥35 kg/m² & 100% T2DM prevalence					
cumulative cost/patient GBP (€)	6050	7983	9851	11656	13399
cumulative cost/patient Conventional (€)	7066	10278	13381	16379	19276
Δ cumulative cost/patient (€)	**-1017**	-2295	-3530	-4724	**-5877**
cumulative utility/patient GBP (QALYs)	0.76	1.44	2.10	2.73	3.34
cumulative utility/patient conventional (QALYs)	0.48	0.88	1.27	1.64	2.00
Δ cumulative utility/patient (QALYs)	**0.28**	0.56	0.84	1.09	**1.34**
ICER over the scope (€/QALY)	-3611	-4065	-4213	-4318	-4385
Budget impact for 1,000 patients (million €)	-1.017	-2.295	-3.530	-4.724	-5.877
AGB vs conventional: baseline BMI ≥35 kg/m² & 100% T2DM prevalence					
cumulative cost/patient AGB (€)	7709	9722	11363	13109	14796
cumulative cost/patient Conventional (€)	7066	10278	13381	16379	19276
Δ cumulative cost/patient (€)	**643**	-556	-2 018	-3 270	**-4480**
cumulative utility/patient AGB (QALYs)	0.63	1.23	1.84	2.45	3.03
cumulative utility/patient conventional (QALYs)	0.48	0.88	1.27	1.64	2.00
Δ cumulative utility/patient (QALYs)	**0.14**	0.35	0.57	0.81	**1.03**
ICER over the scope (€/QALY)	4448	-1594	-3513	-4021	-4357
Budget impact for 1,000 patients (million €)	-0.064	-0.056	-2.0218	-3.270	-4.480

To address this question, the model structure chosen compares two treatment arms over a period of time without crossover. A deterministic model was considered to be suitable for this purpose. If the question addressed here had been to compare outcomes, costs and value-for-money of a therapeutic strategy where surgery would be an option in case of failure of conventional treatment in a patient population where conventional treatment has not yet proven to fail in all individuals, versus a strategy where no bariatric surgery would be proposed even in the case of failure of conventional treatment in the same population, then a time-cycle model with possibilities of crossover from one treatment to the other would have been considered.

Table 13. Output: Incremental cost-utility and budget impact in the UK

Follow-up duration	1 year	2 years	3 years	4 years	5 years
GBP vs conventional: baseline BMI ≥35 kg/m² & 100% T2DM prevalence					
cumulative cost/patient GBP (£)	5489	6443	7366	8258	9121
cumulative cost/patient Conventional (£)	1452	2935	4367	5751	7083
Δ cumulative cost/patient (£)	**4035**	3508	2999	2508	**2033**
cumulative utility/patient GBP (QALYs)	0.76	1.44	2.10	2.73	3.34
cumulative utility/patient conventional (QALYs)	0.48	0.88	1.27	1.64	2.00
Δ cumulative utility/patient (QALYs)	**0.28**	0.56	0.84	1.09	**1.34**
ICER over the scope (£/QALY)	14328	6214	3579	2293	1517
Budget impact for 1,000 patients (million £)	+4.03	+3.51	+3.00	+2.51	+2.03
AGB vs conventional: baseline BMI ≥35 kg/m² & 100% T2DM prevalence					
cumulative cost/patient AGB (£)	4998	6138	8001	8103	9072
cumulative cost/patient Conventional (£)	1452	2935	4367	5751	7088
Δ cumulative cost/patient (£)	**3545**	3204	2733	2352	**1984**
cumulative utility/patient AGB (QALYs)	0.63	1.23	1.84	2.45	3.03
cumulative utility/patient conventional (QALYs)	0.48	0.88	1.27	1.64	2.00
Δ cumulative utility/patient (QALYs)	**0.14**	0.35	0.57	0.81	**1.03**
ICER over the scope (£/QALY)	24511	9185	4758	2886	1929
Budget impact for 1,000 patients (million £)	+3.54	+3.20	+2.73	+2.35	+1.98

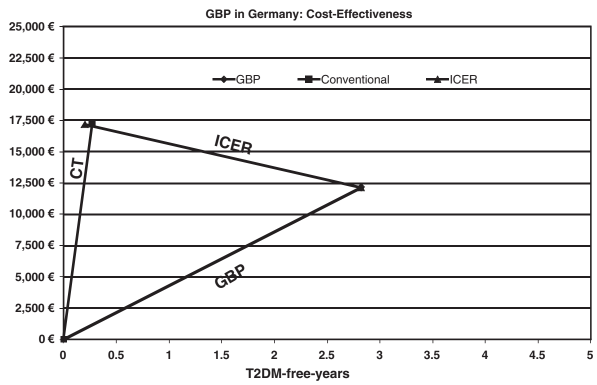


Figure 5. Cost-Effectiveness in €/T2DM-free-year – GBP with BMI ≥35 kg/m² and T2DM – Germany.

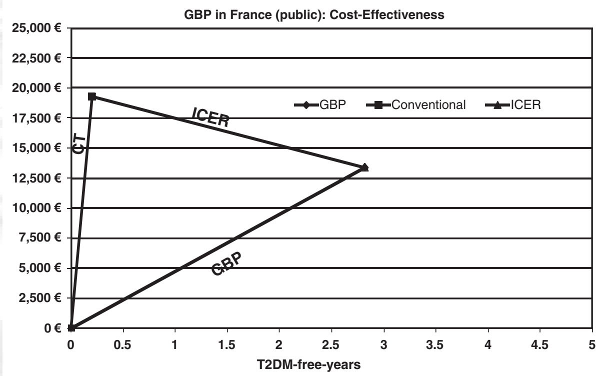


Figure 7. Cost-Effectiveness in €/T2DM-free-year – GBP with BMI ≥35 kg/m² and T2DM – France.

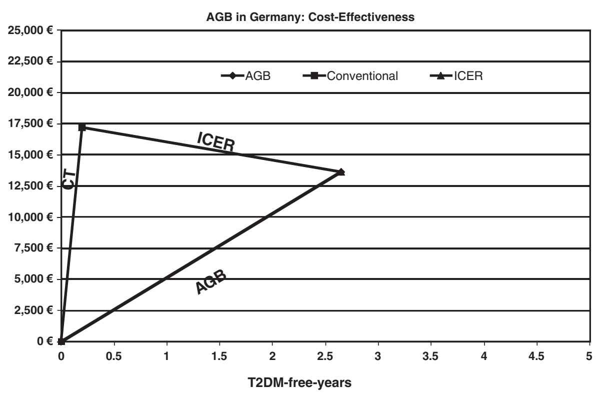


Figure 6. Cost-Effectiveness in €/T2DM-free-year – AGB with BMI ≥35 kg/m² and T2DM – Germany.

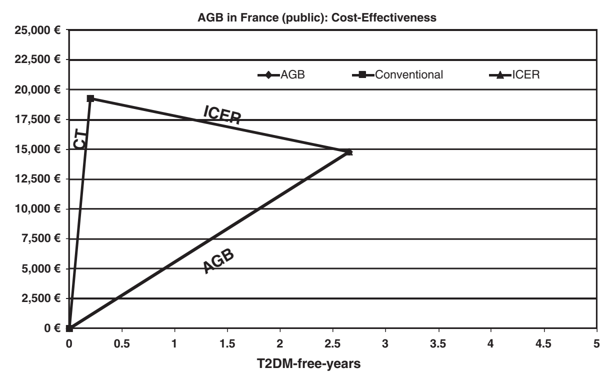


Figure 8. Cost-Effectiveness in €/T2DM-free-year – AGB with BMI ≥35 kg/m² and T2DM – France.

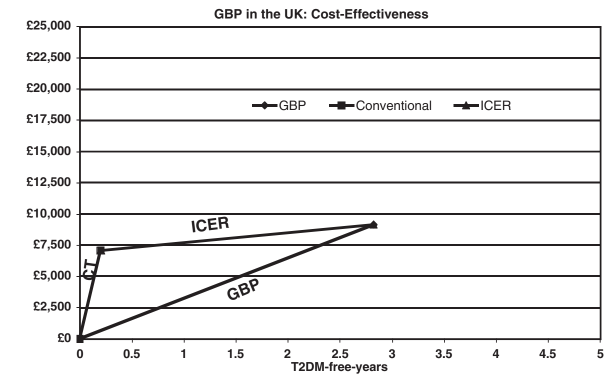


Figure 9. Cost-Effectiveness in €/T2DM-free-year – GBP with BMI ≥35 kg/m² and T2DM – UK.

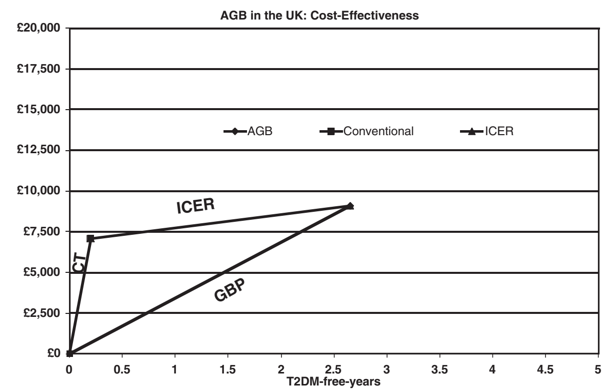


Figure 10. Cost-Effectiveness in €/T2DM-free-year – GBP with BMI ≥35 kg/m² and T2DM – UK.

Markov chains or semi-Makov models are more suitable than deterministic models for such purposes.

Definition of Outcomes: The assumption of this model that a BMI reduction of 1 kg/m² is considered to have the same clinical value whatever the starting BMI, is likely to result in oversimplified outcome calculations, but reported data in eligible publications do not enable pooling of BMI variation in relation to baseline. The assumption of a binary presence or absence of T2DM according to reported prevalence and drug use, ignoring severity levels, is also a source of inaccuracy and biased prevalence estimates, but available published results do not enable a more accurate description.

Relevance of the 5-year Scope: The choice of a 5-year time-scope is based on the recommendation of the National Institute for Clinical Excellence that *"appropriate follow-up for assessing the effectiveness of interventions for morbid obesity should extend to 5 years rather than 1 year"*.[20] All of the assumptions made to establish this model may be discussed. The level of evidence of the source data used to establish the base case is unquestionably a core issue that will need to be regularly reviewed as new evidence becomes available.

Suitability of Conventional Treatment as a Comparator: Defining an appropriate comparator to bariatric surgery is delicate. Given that practice guidelines require that patients should be referred for bariatric surgery only upon failure of at least 1 year of well conducted medical treatment, the logical comparator seems to be watchful waiting. However, expert opinion and medical ethics indicate that even after failure of >1 year of well conducted medical treatment, *continued* conventional treatment will not be denied to a patient with BMI ≥35 kg/m² and T2DM, in spite of evidence of repeated failure, and at best, small temporary improvement. Given that continued conventional treatment can be significantly more costly than watchful waiting, it was considered to be a suitable comparator to bariatric surgery in the base case of a model for calculating budget impact, incremental cost and incremental cost-effectiveness. The programmability of the Excel-based model that we propose, however, enables users to define the comparator as the conventional treatment that they deem to be the most common for patients who would be considered for bariatric surgery, or watchful waiting or *"do nothing"*. The assumption of equal effectiveness with all *continued* conventional treatment modalities was necessary because of the lack of detailed outcomes data in target patients with all conventional options.

Duration of Health Benefit over Time: Several sources of longitudinal evidence report T2DM improvement over at least 3 years after both GBP and AGB. Our base case assumption was a conservative improvement at 5 years (i.e. lower range reduction in T2DM prevalence), based on a reasonably good methodological level of published evidence that mean BMI loss remains significant at that follow-up period. T2DM remission is unlikely to be sustainable with *continued* conventional treatment for >1 year in morbidly obese patients who have previously failed on well conducted conventional treatment.[23,35-44] The empirical utility scale that we have

Table 14. Worse case analysis in T2DM patients: 20% less effective AGB and GBP vs watchful waiting

Follow-up year	1	2	3	4	5	Increment
Inputs						
Conventional – BMI reduction (kg/m^2)	0.0	0.0	0.0	0.0	0.0	0.0
Conventional – T2DM relative prevalence (%)	100	100	100	100	100	0.00
Conventional – QALYs	0.43	0.43	0.43	0.43	0.43	1.93
AGB – BMI reduction (kg/m^2)	-8.0	-9.0	-10.0	-12.0	-10.0	-49.0
AGB – T2DM relative prevalence (%)	50	60	65	65	65	1.95
AGB – QALYs	0.61	0.61	0.62	0.64	0.62	2.79
GBP – BMI reduction (kg/m^2)	-15.0	-14.0	-14.0	-12.5	-12.0	-67.5
GBP – T2DM relative prevalence (%)	50	55	60	60	65	2.10
GBP – QALY	0.71	0.68	0.68	0.66	0.64	3.04
Conventional – Cost Germany (€)						834.48
GBP – Cost Germany (€)						5199.05
AGB – Cost Germany (€)						6047.77
Conventional – Cost France (€)						1704.40
GBP – Cost France (€)						6938.08
AGB – Cost France (€)						8318.19
Conventional – Cost in the UK (£)						739.76
GBP – Cost in the UK (£)						6346.52
AGB – Cost in the UK (£)						6060.18
Outputs Germany						
GBP – conventional: budget impact (million €)						- 2.455
GBP ICER: €/QALY						-2208
GBP ICER: €/BMI.year						- 36.4
GBP ICER: €/T2DM-free-year						- 1169.4
AGB – conventional: budget impact (million €)						- 1.123
AGB ICER: €/QALY						- 1305
AGB ICER: €/BMI.year						- 22.9
AGB ICER: €/T2DM-free-year						-575.9
Outputs France						
GBP – conventional: budget impact (million €)						- 4.448
GBP ICER: €/QALY						- 4 000
GBP ICER: €/BMI.year						- 65.9
GBP ICER: €/T2DM-free-year						- 2118
AGB – conventional: budget impact (million €)						+ 1187
AGB ICER: €/QALY						+1379
AGB ICER: €/BMI.year						+24.2
AGB ICER: €/T2DM-free-year						+ 608.5
Outputs United Kingdom						
GBP – conventional: budget impact (million £)						+ 2.891
GBP ICER: £/QALY						+ 2599
GBP ICER: £/BMI.year						+ 42.8
GBP ICER: £/T2DM-free-year						+ 1376
AGB – conventional: budget impact (million £)						+ 2.797
AGB ICER: £/QALY						+ 3 251
AGB ICER: £/BMI.year						+ 57.1
AGB ICER: £/T2DM-free-year						+ 1434

used to calculate QALYs gained is based on cross-sectional observations. However, longitudinal observations from one study have confirmed an improvement in EQ-5D utility scores after BMI reduction in severe obesity and after T2DM remission.[75] More longitudinal data would be necessary to provide a more solid confirmation, because that study is based on 100 patients only, and such relatively small caseloads may provide insufficient statistical power for the EQ-5D to detect the effect of BMI on health-related utility compared to large samples.[76] With regard to the method that we chose to quantify outcomes in terms of BMI reduction and T2DM improvement, we regard the integration of duration of effect as necessary, because duration is a key aspect of all chronic diseases, including morbid obesity and T2DM. The integration of the time dimension is standard in patient utility quantification through QALYs.

Initial Hospital Admission Costs: The perspective of this model is a payer perspective. As such, the most accurate estimates of charges to payers were sought when this model was prepared in 2004 and 2005. The hospital admission standard all-inclusive payment approach was preferred in countries where such a payment option existed in 2005, at least for some types of institutions. In the case of France, the use of public GHS tariff results is likely to result in an overestimation of the cost per case, compared to costs for social insurers when patients are operated in private clinics. The applicability and/or levels of standard all-inclusive payments will vary through years after 2005, and applicability may vary across types of institutions. Thus, the base case proposed will need to be updated annually and for the various types of institutions. This is enabled by the specifications of the Excel model proposed, although this is out of the scope of this publication.

T2DM Costs: The choice of cost items to be taken into account is related to baseline levels and variation in severity of T2DM, including avoided worsening over the 5-year scope. Whether savings would be gained in relation to avoided complications of T2DM has been insufficiently documented in literature until now, because T2DM improvement reported in most bariatric studies is an observational finding in patients who usually present emerging microvascular disease and are therefore not representative of the typical diabetic population, with no data on the progression of microvascular complications and without specific study design to address this issue.[77] The CODE-2 study reports cost-of-illness data in patients who are more than 20 years older (in their 60s) than patients reported in most bariatric studies, but who present a much lower BMI (usually ≤30) and with a mean time since T2DM diagnosis of about 8 to 9 years. The model that we propose is designed to take into account the full range of T2DM severity from baseline and throughout follow-up, and thus to enable sensitivity analysis with respect to this parameter. Until more clinical evidence becomes available to address this issue, our approach to the base case was to consider that targeted patients with T2DM reported in bariatric studies are reasonably representative of average T2DM patients in terms of costs over the 5 years of the time-scope. T2DM costs reported in CODE-2 were about 5 years old when the base case of this model was calculated and had not been adjusted for annual cost increase. The model is thus likely to yield a conservative estimate of the cost reduction related to T2DM improvement.

How Robust is this Model? How do changes in structural assumptions and base case inputs change the conclusions? The robustness of this Excel-based model should ideally be determined through the comparison of its output ranges during sensitivity analysis with outputs obtained by gold-standard techniques given the same combinations of inputs. In practice, this is very difficult to perform because all possible combinations of inputs and their likelihood are not known. The robustness will therefore be tested over time through use with different input scenarios while output is known beforehand. Given the high level of caution concerning the conclusions obtained in the case of patients with T2DM, especially in Germany and France, the worse case scenario performed was deemed very important. The level of reaction displayed by the model (significant decrease in cost-effectiveness and switch from cost-saving to cost-increase in the case of AGB in France) suggests that the model is a relatively reliable instrument to address the questions for which it has been designed with real life inputs. Moreover, the ability to *BMI.years (kg/m^2.years,) and T2DM-free life years* as an alternative to QALYs removes the inevitable uncertainty related to an interpretation of outcomes as patient-interpreted utility.

Financial support was provided by Ethicon Endo-Surgery for Excel model software development. Frederic Daoud is an external consultant in clinical epidemiology to Ethicon Endo-Surgery.

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(Received June 9, 2006; accepted July 10, 2006)