

Available online at [www.sciencedirect.com](http://www.sciencedirect.com)

Public Health

journal homepage: [www.elsevier.com/puhe](http://www.elsevier.com/puhe)

## Original Research

# Cost-effectiveness of an educational healthcare circuit for bariatric surgery in France



A. Duenas<sup>a,\*</sup>, C. Di Martinelly<sup>b</sup>, A. Aelbrecht<sup>b</sup>, P.-E. Allard<sup>c</sup>,  
J. Rousseaux<sup>c,d</sup>

<sup>a</sup> ICN Business School, CEREFIGE, Nancy, France

<sup>b</sup> IESEG, School of Management, LEM-CNRS (UMR 9221), Lille, France

<sup>c</sup> Ramsay Générale de Santé, Hôpital Privé La Louvière, Lille, France

<sup>d</sup> ELSAN, Paris, France

## ARTICLE INFO

## Article history:

Received 13 June 2018

Received in revised form

6 April 2019

Accepted 25 April 2019

Available online 10 June 2019

## Keywords:

Obesity

Bariatric surgery

Cost-effectiveness

Type 2 diabetes

Cardiovascular diseases

## ABSTRACT

**Objectives:** An educational healthcare circuit (EHC) is proposed with the objective of preventing weight recovery of patients after bariatric surgery through education and lifestyle change. The objective of this study was to measure the viability of the EHC (shared medical appointments [SMAs] combined with bariatric surgery) through cost-effectiveness analysis. The EHC presented in this study is innovative because it offers a multidisciplinary approach based on medical, psychological and dietetic expertise to combat obesity. The strategy is to give the patient a diagnosis and then a personalised follow-up.

**Study design:** A mathematical model based on a decision tree (1 year) and a Markov model (10 years) to measure the efficiency and cost of an EHC in comparison with the customary care offered in France were built.

**Methods:** The effects of the EHC were observed for the prevalence of type 2 diabetes and the risk of cardiovascular disease. The chosen financial perspective is from the point of view of the French social security system.

**Results:** The EHC records an incremental cost-effective ratio (ICER) of € 48,315.43 per quality-adjusted life year (QALY) over a 1-year horizon and € 28,283.77 per QALY over 10 years (with discount rate of 8%: € 25,362.85 per QALY).

**Conclusion:** The results suggest that an EHC is more expensive yet more effective than usual care. That is, in the short term, the costs are high, but at 10 years, the treatment is cost-effective, representing a feasible alternative for those patients who qualify for bariatric surgery in France.

© 2019 The Royal Society for Public Health. Published by Elsevier Ltd. All rights reserved.

\* Corresponding author. ICN Business School, Campus Artem, Office 207 86 rue du Sergent Blandan – CS 70148, FR-54003, Nancy CEDEX, France. Tel.: +33(0)354502573.

E-mail addresses: [alejandra.duenas@icn-artem.com](mailto:alejandra.duenas@icn-artem.com) (A. Duenas), [c.dimartinelly@ieseg.fr](mailto:c.dimartinelly@ieseg.fr) (C. Di Martinelly).

<https://doi.org/10.1016/j.puhe.2019.04.015>

0033-3506/© 2019 The Royal Society for Public Health. Published by Elsevier Ltd. All rights reserved.

## Introduction

Obesity affects more than 11.4 million people in France, representing 17% of the adult population.<sup>1,2</sup> Two sources of obesity can be identified: a genetic predisposition<sup>3</sup> and environmental behavioural causes.<sup>4</sup> Although obesity may be defined as the direct result of a disorder or change in eating behaviour associated with a decline in physical activity, some factors such as stress, pollution, lack of sleep, depression or some medications can also increase weight gain.<sup>5</sup> Finding these factors is a global issue because obesity is considered an illness that is spreading from year to year and is difficult to reverse. The World Health Organization<sup>6</sup> has classified overweight and obesity in terms of body mass index (BMI, in kg/m<sup>2</sup>) as follows: underweight, BMI < 18.5; normal weight, 18.5 ≤ BMI ≤ 24.9; overweight, 25 ≤ BMI ≤ 29.9; obese, BMI ≥ 30. The obese category is divided into obese class I (severe obesity) 30.0 ≤ BMI ≤ 34.9 and obese class II (morbid obesity) 35.0 ≤ BMI ≤ 39.9.

There is a wide range of diseases related to overweight and obesity. These diseases are very diverse and affect different parts of the body, including the cardiac, respiratory and digestive systems. To fight against obesity in a sustainable way, individuals must work on different aspects of their environment and behaviour, which relates to dietary, psychological and physical activity changes. A patient may also resort to medication or surgery. Managing obesity has four major goals: losing weight, stabilising it, treating comorbidities and preventing weight gain.<sup>7</sup>

Finding innovative treatments and care delivery strategies to treat obesity in adults is a worldwide concern; an obesity series published in *The Lancet* in 2015 stresses the need to use multiple therapeutic modalities, relying on different health-care professionals.<sup>8</sup> To be implemented on a wide scale, this new approach has to demonstrate its cost-effectiveness and improve the quality of life of patients. Although benefits and costs of surgical treatments for obesity have been internationally extensively studied,<sup>9–11</sup> there is, to our knowledge, no similar studies for an integrated approach to treat obesity.

The objective of this article was to estimate the cost-effectiveness associated with the implementation of an integrated approach. The model was applied in a French context.

In France, the 'Haute Autorité de Santé' (HAS) strongly recommends the establishment of a therapeutic and multidisciplinary follow-up before and after bariatric surgery to prepare, accompany and prevent patients from possible complications. An educational healthcare circuit (EHC) comprising multidisciplinary shared medical appointments (SMAs) combined with bariatric surgery is proposed with the objective of preventing weight gain of patients after bariatric surgery through education and lifestyle change. Nevertheless, this EHC represents an additional investment which, at the moment, is financed by the Regional Health Authority (Agence Regionale de Sante, ARS). Therefore, the purpose of this study is to demonstrate the viability of the EHC and the importance of investing in it. Two major aspects must therefore be addressed: the cost of the programme and its effectiveness. A mathematical model was built to estimate the cost-effectiveness associated with the implementation of this

programme. The results of the modelling process were measured as the costs incurred in euros and the benefits in terms of quality-adjusted life years (QALYs) gained.

## Methods

### Literature review

The aim of this literature review was not only to find data on costs and effectiveness of bariatric surgery and SMA programmes but also to get an overview of the work already done and the methodology used in this area. The search for content was made on PubMed; only academic articles with the following keywords were included: cost-effectiveness analysis, randomised controlled trial, bariatric surgery, obesity therapeutic education, economic analysis, type 2 diabetes, cardiovascular diseases, Markov model, decision tree analysis.

The inclusion and exclusion criteria for studies were as follows: (a) type of research, i.e. randomised controlled trials, longitudinal analyses, observational studies, economic health assessments and cost-effectiveness analyses; (b) surgery, i.e. gastric bypass, sleeve gastrectomy and gastric band; (c) languages: English, French and Spanish; (d) setting of the study: European countries, United States and Canada; (e) population: obesity in adults (18–65 years), BMI greater than 40 or greater than 35 if associated comorbidities; (f) study dating back less than 10 years. Although some medical research articles question the validity and reliability of the BMI as a measure of obesity,<sup>12–14</sup> it was decided to use it as the French health services recommend bariatric surgery based on that measurement.<sup>15</sup>

The treatment proposed in this study is the preparation for obesity surgery. The population for the EHC is men or women, aged between 18 and 65 years with a BMI >30. These patients can subsequently decide to have surgery if their BMI is between 35 > BMI > 40 (+associated comorbidity) or BMI > 40.

The intervention under review is the EHC, which consists of multidisciplinary SMAs combined with bariatric surgery. The EHC consists of different stages. At the beginning of the process, the patient meets a nutritionist, a dietician and a psychologist who conduct a multidisciplinary evaluation. Then, an individualised EHC with SMAs along with individual consultations is proposed to the patient. The SMA offers a multidisciplinary approach based on medical, dietary and psychological expertise. There are 6 group sessions (10 people per session approximately) of 2 h each. The strategy is to offer the patient a follow-up according to behaviour and needs. Four types of medical and therapeutic follow-up sessions, based on the patient's requirements, are offered. Patients eligible for bariatric surgery are referred to the surgical programme. Patients with emotional disorders receive additional psychological counselling. Work on food behaviour is proposed for patients with cognitive restriction. Finally, patients are systematically involved in a nutritional support programme.

Patients having surgery profit from additional information given by an expert in the area. Preoperative examinations are conducted during 3 days of hospitalisation along with

psychological and medical consultations. For patients undergoing bariatric surgery, the duration of the EHC is approximately 4–6 months from the first multidisciplinary evaluation until the surgery (although it could be longer for patients in need of further medical or psychological consultations).

The comparator is usual care, which will be considered as only surgery without any presurgery intervention but the usual preoperative tests.

The estimated outcomes are the costs incurred in euros and the health-related benefits measured in terms of QALYs reported as the cost per QALY gained or incremental cost-effective ratios (ICERs).

### Structure of the economic model

The model assesses the economic consequences of the EHC in terms of cost of care and good value for the money spent. The French health authority HAS (Haute Autorité de Santé) suggests not to place a value on life years as a function of individual characteristics. Therefore, it recommends not integrating indirect costs in the ICER.<sup>16</sup> Because it was decided to have a health service perspective, indirect costs such as labour market access<sup>17</sup> or loss of productivity<sup>11</sup> were not considered even though these can be very high. The economic model consists of two parts: a short-term element, based on a decision tree with a one-year time horizon and a long-term element, based on a Markov model, which extrapolates patient costs, outcomes and health states over a 10-year time horizon. The perspective chosen for this analysis is that of the French social security. The model considered two health outcomes: the presence of type II diabetes, over the entire time horizon (short and long term), and the presence or onset of cardiovascular disease in the long term.

#### Short-term model

For this analysis, it was decided to highlight the direct consequences of an EHC combined with bariatric surgery on type 2 diabetes (in terms of cost and utility). The EHC (presurgery and surgery) lasts approximately 6 months, and the post-surgery effects were calculated 6 months after intervention. The choice of type 2 diabetes was made because bariatric surgery has been a proven treatment for this disease with a remission rate of 72% within 2 years after surgery.<sup>18</sup> Because the EHC has no direct effect on type 2 diabetes, its impact when compared with usual care can be only perceived in terms of quality of life after the intervention or a decrease in diabetes due to a change in lifestyle and behaviour.

When a patient has completed all the preoperative stages, on either the EHC or usual care branches, he/she has the choice to continue with surgery based on the advice of the doctors caring for him/her. Some patients may refuse surgery because of certain psychological or physical factors. Surgery can lead to success, complications or death (in some cases). The short-term model is structured as a decision tree shown in [Appendix 1](#), with a one-year time horizon. The decision tree traces these stages, ending with state of health including the presence of type 2 diabetes or not.

Probabilities of clinical events, complications and outcomes of the surgical procedures were derived from the literature review and are presented in [Table 1](#). In France, the

majority of surgical procedures are sleeve gastrectomy (46%), followed by bypass (30%) and the gastric band (24%).<sup>19</sup> To estimate the mortality after 30 days of bariatric surgery, the study developed by the Michigan Bariatric Surgery Collaborative (MBSC) was used.<sup>20</sup> A similar study was used to estimate the probability of patients having short-term complications after bariatric surgery.<sup>21</sup> It was assumed that in the EHC branch, there were no early or secondary complications from the gastric band surgery in the short term because there were no deaths. In the gastric bypass and sleeve gastrectomy cases, only 6.7% and 7.9% of patients had complications, respectively. The early mortality rate during the intervention is assumed to be 0%.

The risk of having diabetes among non-diabetic obese patients up to 7 years after surgery was obtained from a UK study.<sup>22</sup> The risk of diabetes in the first year after surgery for gastric bypass, adjustable gastric band and sleeve gastrectomy were reported in the study by Buchwald et al.<sup>23</sup> The rate of diabetes remission among non-surgical patients was estimated at 6.9% (95% confidence interval [CI], 6.9%, 7.1%).<sup>24</sup> According to Arterburn et al.<sup>24</sup> the risk of dying from diabetes in the year after intervention is 0.35% for patients who have undergone surgery and 0.77% for patients who have not undergone bariatric surgery.

Bariatric surgery is very effective in terms of weight loss but can also present a danger if there are complications. The risk of complications after surgery is 13%, including 1% of deaths.<sup>28</sup> There are two types of complications: medical complications and surgical complications. Possible medical complications are myocardial infarction, pulmonary embolism or pulmonary and urinary infections. These complications are all more likely to arise if the patient has a BMI >50, especially if it is a man older than 45 years who has a history of hypertension. Some surgical complications, such as trocar accidents (2%), are common to all bariatric interventions; others are specific to the type of surgery. For gastric band, the most common complication is gastric or oesophageal perforation. This complication requires reintervention. In 13% of cases, the patient may experience dilation of the oesophagus, which prevents him/her from feeding. Finally, the displacement of the ring can also be dangerous for the patient (2–8% of cases).<sup>29</sup> Early complications of irreversible bariatric interventions consist mainly of fistula and haemorrhage. The fistula rate is about 2% after a bypass and 4% after a sleeve gastrectomy.<sup>28</sup>

After a bypass, the most frequently encountered complications are anastomotic stenosis (6% of cases), ulcers (2%) and side-effects such as internal hernia, adhesions, occlusions at the level of the foot, 'anse' (upper part of the stomach) or trocar orifices.<sup>28</sup> Finally, gastric stenosis and 'gastro-oesophageal reflux' occur in 12% of cases.<sup>28</sup> These two complications are most often treated by endoscopy, surgery being reserved for the most serious cases.

**Surgery preparation programme costs.** Health insurance for the EHC with presurgery procedures (code Classification commune des actes médicaux (CCAM) is quoted at € 2,458,22 per patient. In addition, each patient registered at the EHC will have extra costs of € 188.15 and 7 therapeutic follow-up sessions funded by the ARS at € 300 per patient. The total presurgery treatment costs € 2,946,37 per patient.

**Table 1 – Decision tree probabilities and sources.**

Decision tree node	Probabilities		Sources	
	EHC	Usual care	EHC	Usual care
Node A – surgery	0.819	0.800	Expert data	Expert data
Node B – gastric bypass (GB)	0.217	0.295	Denimal et al. <sup>25</sup>	CNAM <sup>19</sup>
Node C – survive (GB)	0.992	0.992	Finks et al. <sup>20</sup>	
Node D – complications (GB)	0.067	0.031	PMSI <sup>26</sup>	Birkmeyer et al. <sup>21</sup>
Node E – death (GB)	0.000	0.001	Birkmeyer et al. <sup>21</sup>	
Node F – without comorbidities (GB – complications)	0.957	0.976	Buchwald et al. <sup>23</sup>	Buchwald et al. <sup>23</sup>
			Booth et al. <sup>22</sup>	Booth et al. <sup>22</sup>
			Denimal et al. <sup>25</sup>	CNAM <sup>19</sup>
Node G – diabetes (GB – complications)	0.996	0.996	Arterburn et al. <sup>24</sup>	Arterburn et al. <sup>24</sup>
			Denimal et al. <sup>25</sup>	
Node H – without comorbidities (GB – no complications)	0.957	0.976	Buchwald et al. <sup>23</sup>	Buchwald et al. <sup>23</sup>
			Booth et al. <sup>22</sup>	Booth et al. <sup>22</sup>
			Denimal et al. <sup>25</sup>	CNAM <sup>19</sup>
Node I – diabetes (GB – no complications)	0.996	0.996	Arterburn et al. <sup>24</sup>	Arterburn et al. <sup>24</sup>
			Denimal et al. <sup>25</sup>	
Node J – Gastrectomie Longitudinale (sleeve gastrectomy) (GL)	0.645	0.459	Expert data	CNAM <sup>19</sup>
Node K – survive (GL)	0.995	0.995	Finks et al. <sup>20</sup>	
Node L – complications (GL)	0.079	0.022	Expert data	Birkmeyer et al. <sup>21</sup>
Node M – death (GL)	0.000	0.000	Birkmeyer et al. <sup>21</sup>	
Node N – without comorbidities (GL – complications)	0.959	0.963	Richdeep et al. <sup>27</sup>	Richdeep et al. <sup>27</sup>
			Booth et al. <sup>22</sup>	Booth et al. <sup>22</sup>
			Denimal et al. <sup>25</sup>	CNAM <sup>19</sup>
Node O – diabetes (GL – complications)	0.996	0.996	Arterburn et al. <sup>24</sup>	Arterburn et al. <sup>24</sup>
			Denimal et al. <sup>25</sup>	
Node P – without comorbidities (GL – no complications)	0.959	0.963	Richdeep et al. <sup>27</sup>	Richdeep et al. <sup>27</sup>
			Booth et al. <sup>22</sup>	Booth et al. <sup>22</sup>
			Denimal et al. <sup>25</sup>	CNAM <sup>19</sup>
Node Q – diabetes (GL – no complications)	0.996	0.996	Arterburn et al. <sup>24</sup>	Arterburn et al. <sup>24</sup>
			Denimal et al. <sup>25</sup>	
Node R – adjustable gastric band (AGB)	0.138	0.246	Expert data	CNAM <sup>19</sup>
Node S – survive (AGB)	0.998	0.998	Finks et al. <sup>20</sup>	
Node T – complications (AGB)	0.000	0.008	Expert data	Birkmeyer et al. <sup>21</sup>
Node U – death (AGB)	0.000	0.000	Expert data	Birkmeyer et al. <sup>21</sup>
Node V – without comorbidities (AGB – complications)	0.912	0.936	Buchwald et al. <sup>23</sup>	Buchwald et al. <sup>23</sup>
			Booth et al. <sup>22</sup>	Booth et al. <sup>22</sup>
			Denimal et al. <sup>25</sup>	CNAM <sup>19</sup>
Node W – diabetes (AGB – complications)	0.996	0.996	Arterburn et al. <sup>24</sup>	Arterburn et al. <sup>24</sup>
			Denimal et al. <sup>25</sup>	
Node X – without comorbidities (AGB – no complications)	0.912	0.936	Buchwald et al. <sup>23</sup>	Buchwald et al. <sup>23</sup>
			Booth et al. <sup>22</sup>	Booth et al. <sup>22</sup>
			Denimal et al. <sup>25</sup>	CNAM <sup>19</sup>
Node Y – diabetes (AGB – no complications)	0.996	0.996	Arterburn et al. <sup>24</sup>	Arterburn et al. <sup>24</sup>
			Denimal et al. <sup>25</sup>	
Node Z – survive (no surgery)	1000	1000		
Node AA – without comorbidities (no surgery)	0.829	0.866	Arterburn et al. <sup>24</sup>	Arterburn et al. <sup>24</sup>
			Booth et al. <sup>22</sup>	Booth et al. <sup>22</sup>
			Denimal et al. <sup>25</sup>	CNAM <sup>19</sup>
Node AB – diabetes (no surgery)	0.992	0.992	Arterburn et al. <sup>24</sup>	Arterburn et al. <sup>24</sup>

CNAM, Caisse Nationale - l'Assurance Maladie; PMSI, programme de médicalisation des systèmes d'information; EHC, educational healthcare circuit.

Patients who follow the usual care branch will not be offered an EHC and will not spend 3 days in hospital for tests. Patients consult a nutritionist and a psychologist for at least three and five sessions, respectively, before having surgical intervention. Thus, the total amount of preoperative procedures would be € 2316.30 per patient.

**Bariatric surgery costs.** The total costs generated by gastric bypass, sleeve gastrectomy and adjustable gastric band for

both arms, SMA and usual care, are presented in [Appendix 2](#). Surgery rates for usual care are similar to those of EHC, with the only difference being that the average length of stay varies. It is estimated that 5, 4 and 2 days are required for bypass,<sup>30</sup> sleeve gastrectomy<sup>31</sup> and gastric band,<sup>32</sup> respectively. Thus, the costs of the procedures are a bit higher than that of the EHC. In addition, half of the patients are treated because of comorbidities or associated treatment (hypertension, diabetes, sleep apnoea, etc.). It is considered that these

comorbidities can lead to a high level of severity of order 3 or 4 at the rate of 2% and 1% of the population.<sup>33</sup>

Surgical complication costs on average for both EHC and usual care are also presented in [Appendix 2](#).

**Utilities.** Lee et al.<sup>34</sup> developed a regression model to predict EuroQol five dimension scale (EQ-5D) scores for patients based on BMI, age and the presence of diabetes ([Appendix 3](#)).

A study by Rothberg et al.<sup>35</sup> demonstrated that continuing an SMA programme with a low-calorie diet, exercise and behavioural counselling increases the EQ-5D score by 0.06 (95% CI, 0.06,0.17) at the end 6 months.

#### Long-term model

The short-term model studied the effect of therapeutic patient education before bariatric surgery on type 2 diabetes. The long-term model takes the form of a 4-state Markov process as illustrated in [Appendix 4](#); depending on the progress through the short-term model, these estimates are extrapolated over the long term (10 years) and include cardiovascular disease.

In addition to having an immediate effect on type 2 diabetes, bariatric surgery allows both long-term remission (proven to last up to 10 years) and prevents cardiovascular diseases (being one of the leading causes of death in obese and overweight people<sup>36</sup>). Thus, an individual who has undergone obesity surgery has a 9.9% chance of having a cardiovascular event, while a person who has not undergone surgery has a risk of 11.50%.<sup>37</sup>

A patient suffering from type 2 diabetes can be treated and the pathology can be eradicated, just as a patient who has never shown signs of type 2 diabetes may one day develop it. Diabetes or not, an individual may be prone to cardiovascular disease. Cardiovascular diseases include myocardial infarction (heart attack), angina pectoris, cerebrovascular accidents and peripheral heart disease. These diseases are usually irreversible and leave behind sequelae; therefore, in the model, a patient in a cardiovascular disease state remains in it.<sup>38</sup> It was decided to use a Swedish study ‘Swedish Obese Subjects’ (SOS)<sup>39</sup> because no data in France for the SMA programme together with bariatric surgery were available.

Finally, the model estimated the costs (euros) and utilities (QALYs) associated with each event. The discount rate used is 8%.<sup>40</sup> A cycle is defined as a year. The point of view adopted in this analysis remains that of the French social security.

The transition probabilities used in the long-term model are shown in [Appendix 5](#) and are based on a cycle length of one

year. The SOS study was used to calculate the transition probabilities for cardiovascular events for both cohorts operated and non-operated, as well as the number of those that were fatal.<sup>41</sup> The number of fatal events that were not related to cardiovascular events (i.e. cancers, infections, pulmonary embolism) was obtained from the study by Sjöström et al.<sup>42</sup> A British study has shown that among obese non-diabetic patients, there is a 28.2% incidence of diabetes per patient per year in non-operated patients and 5.7% in patients operated on for obesity.<sup>22</sup> In addition, among diabetic patients, it is known that 36% of patients who underwent operation recovered from diabetes within 10 years after surgery and 13% of those treated medically also recovered.<sup>18</sup> There is an average annual remission rate of 3.6% and 1.3%, respectively, for operated and non-operated patients. The mortality rate of patients with diabetes in France is 12 per 100,000 or 0.012%.<sup>43</sup> Finally, the risk of having cardiovascular disease for SMA programme patients was estimated from the Framingham score.<sup>44</sup>

Patients in the EHC are followed up after surgery, having three consultations with the nutritionist in the year after the surgery and two consultations with the surgeon. After that, there one consultation with the nutritionist per year for 3 years. In France, it is recommended that a patient consults his/her general physician or nutritionist at least four times in the year after the intervention and at least once in the next three years.<sup>33</sup> This postoperative follow-up is estimated at an average cost per year of € 14.72 for the SMA programme and € 12.88 for the external sector. The annual cost per patient of cardiovascular disease in France is estimated at € 4730.04.<sup>45</sup> Finally, a patient with type 2 diabetes costs the social security about € 4890 per year.<sup>46</sup>

The EQ-5D score of the general population in France is 0.83 ( $\pm 0.15$ ).<sup>47</sup> The average utility of a patient with type 2 diabetes in France has a score of 0.42 (95% CI = 0.425, 0.433). Finally, cardiovascular diseases also affect the quality of life of patients. A score of 0.604 (95% CI = 0.5737, 0.6255) is obtained for patients who have had at least one cardiac event.<sup>48</sup>

## Results

### Results of the short- and long-term models

[Table 2](#) presents the cost-effectiveness ratios and shows that the EHC is more expensive but more effective. The EHC offers

**Table 2 – Results of the short- and long-term models.**

Interventions	Costs	QALYs	Incremental costs	Incremental QALYs	ICER
Results of the decision tree (1 year)					
EHC	€ 9 960.50	0.72	€ 2 659.72	0.06	€ 61,640.28
Usual care	€ 6 567.27	0.67			
Results of the Markov model (10 years)					
EHC	€ 6882.15	7.11	€ 1316.50	0.05	€ 28,283.77
Usual care	€ 5565.65	7.07			
Results of the Markov model (10 years), discounted					
EHC	€ 4355.37	4.79	€ 825.70	0.03	€ 25,362.85
Usual care	€ 3529.67	4.76			

QALY, quality-adjusted life year; ICER, incremental cost-effective ratio; EHC, educational healthcare circuit.

extra services but with a higher cost. Nevertheless, the cost is justified because the programme provides a real improvement in the quality of life of the patient.

There is no official threshold for France; however, an unofficial value of €50,000 is used.<sup>49</sup> In the short term, given this threshold, the SMA programme is not cost-effective. However, over a 10-year horizon, there is a clear difference with an ICER below the threshold shown in Table 2. While the programme is more expensive, it is considered that this extra cost is justified by the increase in the quality of life of the patient – the project then becomes both feasible and increasingly practicable in the long term.

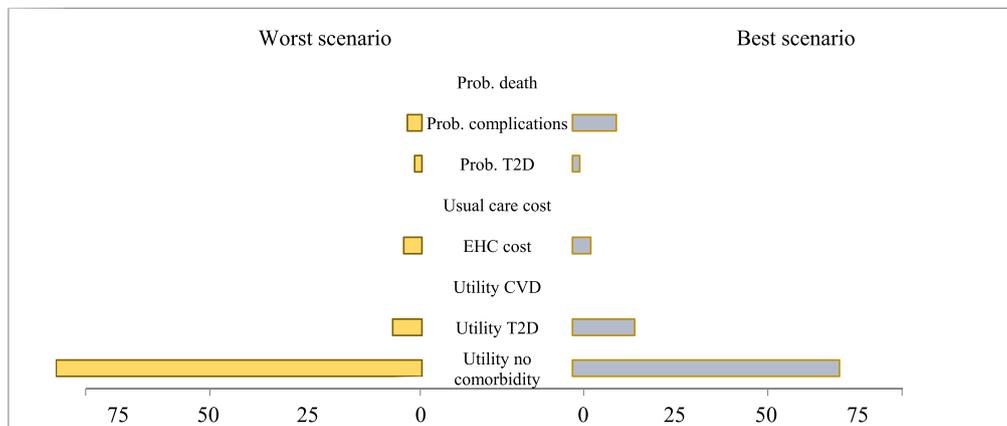
Because this research focuses on reimbursement from the French health services perspective, the economic evaluation was performed with an overall population and not subgroups, e.g. gender. In view of the heterogeneity of the health effects or costs, an analysis of subgroups may be relevant; however, not all the clinical studies used to populate the model included such subgroup analyses, making it difficult to be considered. Studies<sup>17</sup> show that there may be differences between subgroups such as male and female in terms of indirect cost,

which then introduces the possibility of there being an effect on direct costs. This may be considered for further research.

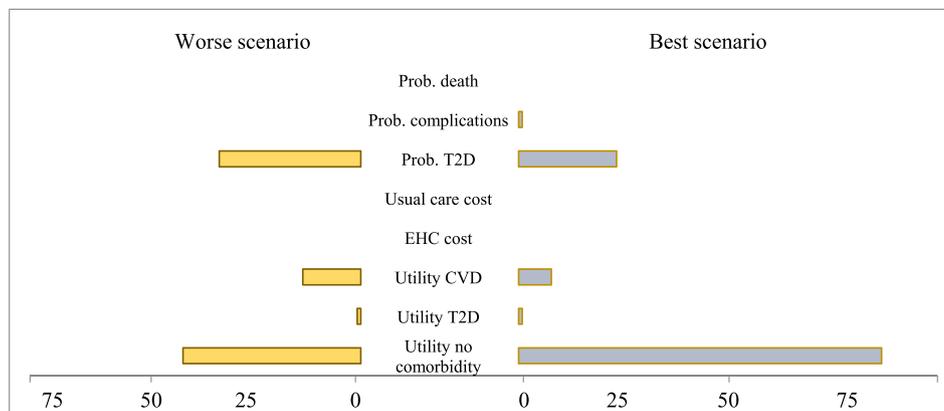
### Results of the sensitivity analyses

One-way sensibility analyses were conducted to determine the parameters that had most influence on the results of the model. The following tornado charts demonstrate the impact of changes on results as a percentage. Standard deviations were used in both directions: the best- and the worst-case scenario. For costs, a variation of  $\pm 5\%$  was chosen. The discount rate was changed by  $\pm 3\%$ . The analysis was conducted for the decision tree and the Markov model with and without discount (Figs. 1, 2 and 3).

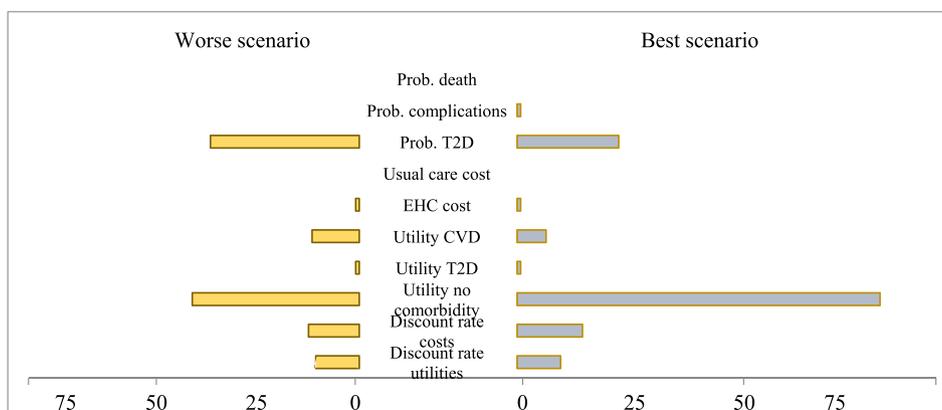
The sensitivity analysis shows us that the most influential parameters of the model are the utilities. In addition, the probability of remission or relapse into diabetes varies significantly. This flaw in the model is probably due to the lack of complete data. The utilities and the risk of diabetes were the result of a calculation based on data that differed from the literature.



**Fig. 1 – Decision tree sensitivity analysis results. T2D, type 2 diabetes; CVD, cardiovascular disease; EHC, educational healthcare circuit; Prob., probability.**



**Fig. 2 – Markov model sensitivity analysis results. T2D, type 2 diabetes; CVD, cardiovascular disease; EHC, educational healthcare circuit; Prob., probability.**



**Fig. 3 – Markov model sensitivity analysis results (8% discounted). T2D, type 2 diabetes; CVD, cardiovascular disease; EHC, educational healthcare circuit; Prob., probability.**

## Discussion

The EHC presented in this study is innovative in terms of tackling obesity because it offers different and more advanced services in terms of support for obese people. However, it represents an additional cost for the state. In the current economic environment and over the short term, this cost is challenging but becomes increasingly interesting in the long term. The EHC (SMA + bariatric surgery) clearly provides a greater improvement in the quality of life than usual care (before surgery + bariatric surgery) programmes. To support the development of multidisciplinary SMAs, changes are needed in the clinical delivery system to equip healthcare professionals with the skills necessary for the treatment and ability to work in team. It may lead to a redefinition of professional competencies and licencing to address obesity. It may also result in the restructuring of services in hospitals as treatments increase in complexity and therefore need more multidisciplinary solutions and interventions. From the health services perspective, it may be a first step for the French authorities towards reimbursement for this kind of intervention.

## Limitations

The model used in this research has some limitations because the EHC population data are very limited, so many of the values were estimated. Moreover, the comparison population was taken from French national data, and it was presupposed that it is similar to the population of the SOS study. The data used in the model were taken from publications issued outside France; therefore, it may differ somewhat from the obese population in France. The sensitivity analyses showed that utilities are a sensitive factor in the model; however, it is important to bear in mind that they were taken from the literature only. Finally, the costs can vary considerably depending on the procedures related to surgery (including complications). It is therefore important to take the results with some caution because the

actual effect on patients' quality of life is not entirely representative of the population and treatments in the study. The model used has a fair and well-established structure; therefore, it is possible to assume validity. The longest registered follow-up by the SOS study has low compliancy in a period of 20 years, so the long-term benefits of bariatric surgery may well have been overestimated.

## Recommendations and future research

This analysis can be improved based on observations and the application of the EQ-5D questionnaire. In addition, as the SOS study showed, long-term follow-up is necessary because obesity is a chronic disease that surgery alone cannot cure. It is important to bear in mind that this economic evaluation is the first of its kind performed for this EHC in France and could be used as a starting point for further research and a way to access financial support for this programme from the French social security system.

## Author statements

The views expressed in this manuscript are those of the authors and do not necessarily reflect those of the Hôpital Privé La Louvière or the French Social Security.

## Ethical approval

Not required because the data used to populate the model were retrospective or secondary.

## Funding

Not funded.

## Competing interests

None declared.

## REFERENCES

1. Équipe de surveillance et d'épidémiologie nutritionnelle (Esen). *Étude de santé sur l'environnement, la biosurveillance, l'activité physique et la nutrition (Esteban), 2014-2016 Volet Nutrition. Chapitre Corpulence. Saint-Maurice: Santé Publique France. 2017. Report No.: 979-10-289-0346-6.*
2. Matta J, Carette C, Rives Lange C, Czernichow S. *Épidémiologie de l'obésité en France et dans le monde. La Presse Médicale; 2018.*
3. Pérusse L. Les bases génétiques de l'obésité humaine : résultats des études d'épidémiologie génétiques. *Ann Endocrinol* 2000;61:24.
4. Bellisari A. Evolutionary origins of obesity. *Obes Rev* 2008;9:165–80.
5. Basdevant A. Obésité. INSERM [serial on the internet]. 2014. Available from: [www.inserm.fr](http://www.inserm.fr).
6. Organization WH. Obesity and overweight - fact sheet. 2018. 28/04/2018]: Available from: <http://www.who.int/mediacentre/factsheets/fs311/en/>.
7. Viez M-C. *La prise en charge de l'obésité en France. Paris: FHP. 2009.*
8. Dietz W, Baur L, Hall K, Puhl RM, Taveras EM, Uauy R, Kopelman P. Management of obesity: improvement of health-care training and systems for prevention and care. *The Lancet* 2015;385:2521–33.
9. Chang S-H, Stoll CRT, Colditz GA. Cost-effectiveness of bariatric surgery: should it be universally available? *Maturitas* 2011;69:230–8. <https://doi.org/10.1016/j.maturitas.2011.04.007>.
10. Gulliford MC, Charlton J, Prevost T, Booth H, Fildes A, Ashworth M, Littlejohns P, Reddy M, Khan O, Rudisill C. Costs and outcomes of increasing access to bariatric surgery: cohort study and cost-effectiveness analysis using electronic health records. *Value Health* 2017;20:85–92. <https://doi.org/10.1016/j.jval.2016.08.734>.
11. Terranova L, Busetto L, Vestri A, Zappa MA. Bariatric surgery: cost-effectiveness and budget impact. *Obes Surg* 2012;22:646–53. <https://doi.org/10.1007/s11695-012-0608-1>.
12. Gelber RP, Gaziano JM, Orav E, Manson JE, Kurth T. Measures of obesity and cardiovascular risk among men and women. *J Am Coll Cardiol* 2008;52:605–15.
13. Völzke H, Schneider HJ, Stalla GK, Wallaschofski H, Nauck M, Friedrich N, Wittchen H-U, Klotsche J, Pieper L, John U, Dörr M, Felix S, Lehnert H, Pittrow D, Silber S. The predictive value of different measures of obesity for incident cardiovascular events and mortality. *J Clin Endocrinol Metab* 2010;95:1777–85. <https://doi.org/10.1210/jc.2009-1584>.
14. Welborn TA, Dhaliwal SS. Preferred clinical measures of central obesity for predicting mortality. *Eur J Clin Nutr* 2007;61:1373.
15. maladi L'assurance. *Obésité de l'adulte : traitement médicamenteux et chirurgical. 2019. https://www.ameli.fr/assure/sante/themes/surpoids-adulte/traitement-medicamenteux-chirurgical.*
16. Department of Economics and Public Health Assessment, Haute Autorité de Santé. *Choices in methods for economic evaluations. 2012.*
17. Johansson E, Böckerman P, Kiiskinen U, Heliövaara M. Obesity and labour market success in Finland: the difference between having a high BMI and being fat. *Econ Hum Biol* 2009;7:36–45. <https://doi.org/10.1016/j.ehb.2009.01.008>.
18. Sjöström L, Lindroos A-K, Peltonen M, Torgerson J, Bouchard C, Carlsson B, et al. Lifestyle, diabetes, and cardiovascular risk factors 10 Years after bariatric surgery. *N Engl J Med* 2004;351:2683. 93.
19. CNAM. *Etude de la chirurgie bariatrique en 2011- Chirurgie de l'obésité : analyse des pratiques et de leur pertinence. 2013. Available from: www.ameli.fr.*
20. Finks J, Kole K, Yenumula P, English W, Krause K, Carlin A, et al. Predicting risk for serious complications with bariatric surgery: results from the Michigan bariatric surgery collaborative. *Ann Surg* 2011;254:633–40.
21. Birkmeyer N, Dimick J, Share D, Hawasli A, English W, Genaw J, et al. Hospital complication rates with bariatric surgery in Michigan. *J Am Med Assoc* 2010;304:435–42.
22. Booth H, Khan O, Prevost T, Reddy M, Dregan A, Charlton J, et al. Incidence of type 2 diabetes after bariatric surgery: population-based matched cohort study. *Lancet Diabetes Endocrinol* 2014;2:963–8.
23. Buchwald H, Avidor Y, Braunwald E, Jensen M, Pories W, Fahrenbach K, et al. Bariatric Surgery - a systematic review and meta-analysis. *J Am Med Assoc* 2004;292:1724–8.
24. Arterburn D, Bogart A, Coleman K, Haneuse S, Selby J, Sherwood N, et al. Comparative effectiveness of bariatric surgery vs. nonsurgical treatment of type 2 diabetes among severely obese adults. *Obes Res* 2013;7:258–68.
25. Denimal F, Arnalsteen L, Lamblin A. *Données Louvière. Lille, Nord-Pas-de-Calais, France. Cabinet des chirurgien viscéraux de l'hôpital privé de la Louvière; 2015.*
26. *Obésité pour Céliobe. Lille, Nord-Pas-de-Calais, France. Hôpital Privée de la Louvière; 2015.*
27. Richdeep GS, Birch DW, Shi X, Sharma A, Karmali S. *Sleeve gastrectomy and type 2 diabetes mellitus: a systematic review. Surgery For Obesity and Related Diseases; 2010.*
28. Gugenheim J, editor. *MORBIDITE ET MORTALITE APRES CHIRURGIE BARIATRIQUE. Prise en charge des complications de la chirurgie de l'obésité. Nice: Congrès de l'Association Française de Chirurgie; 2009.*
29. Chevallier J-M. *Les complications des anneaux gastriques. chirurgie-viscerale.org; 2005.*
30. Haute Autorité de Santé Technique du bypass gastrique (ou court-circuit gastrique) Haute Autorité de Santé [serial on the Internet]. 2009. Available from: [www.has-sante.fr](http://www.has-sante.fr).
31. Autorité de Santé Haute. *Technique de la gastrectomie longitudinale (ou gastrectomie en manchon ou sleeve gastrectomy) Haute Autorité de Santé [serial on the Internet]. 2009. Available from: www.has-sante.fr.*
32. Haute Autorité de Santé. *Technique de l'anneau gastrique ajustable Haute Autorité de Santé [serial on the Internet]. 2009. Available from: www.has-sante.fr.*
33. Haute Autorité de Santé. *Obésité : prise en charge chirurgicale chez l'adulte Paris. Haute Autorité de Santé; 2009.*
34. Lee AJ, Morgan CL, Morrissey AJ, Wittrup-Jensen KU, Kennedy-Martin T, Currie CJ. Evaluation of the association between the EQ-5Dindex (health-related utility) and body mass index (obesity) in hospital-treated people with Type 1 diabetes, Type 2 diabetes and with no diagnosed diabetes. *Diabet Med* 2005;22:1482–6.
35. Rothberg A, McEwen L, Kraftson A, Neshewat G, Fowler C, Burant C, et al. The impact of weight loss on health-related quality-of-life: implications for cost-effectiveness analyses. *Qual Life Res* 2014;23:1371–6.
36. Sjöström L. *Surgical treatment of obesity: an overview and results from the SOS study. Handbook of Obesity. New York: Marcel & Dekker; 2004. p. 359–89.*
37. Sjöström L, Peltonen M, Jacobson P, Sjöström D, Karason K, Wedel H, et al. Bariatric surgery and long-term cardiovascular events. *J Am Med Assoc* 2012;307:56–65.
38. Borisenko O, Adam D, Funch-Jensen P, Ahmed A, Zhang R, Colpan Z, et al. Bariatric surgery can lead to net cost saving to health care systems: results from a comprehensive European decision analytic model. *Obes Surg* 2015;1–10.

39. Lissner L, Lindroos A, Sjöström L. Swedish obese subjects (SOS): an obesity intervention study with a nutritional perspective. *Eur J Clin Nutr* 1998;52:316–22.
40. Evans D. A social discount rate for France. *Appl Econ Lett* 2004;11:803–8.
41. Sjöström L. Review of the key results from the Swedish Obese Subjects (SOS) trial – a prospective controlled intervention study of bariatric surgery. *J Intern Med* 2013;273:219–34.
42. Sjöström L, Narbro K, Sjöström D, Karason K, Larsson B, Wedel H, et al. Effects of bariatric surgery on mortality in Swedish obese subjects. *N Engl J Med* 2007;357:741–52.
43. EUCID. *Final report European core indicators in diabetes project: health & consumer protection*. 2006.
44. D'Agostino RS, Vasan R, Pencina M, Wolf P, Cobain M, Massaro J, et al. General cardiovascular risk profile for use in primary care : the Framingham Heart Study. *Circulation* 2008;117:743–53.
45. Caisse Nationale l'Assurance Maladie. *Coût des ALD en 2009 dans la population du régime général*. ameli. 2009.
46. Ricci P, Chantry M, Detournay B, Poutignat N, Kusnik-Joinville O, Raimond V, et al. Analyse économique des soins des personnes traitées pour diabète (études Entred 2001 et 2007). *Pratiques Organ Soins* 2010;41:1–10.
47. Perneger T, Combescurre C, Courvoisier D. General population reference values for the French version of the EuroQol EQ-5D health utility instrument. *Value in Health* 2010;13:631–5.
48. Ara R, Brazier J. Health related quality of life by age, gender and history of cardiovascular disease: results from the Health Survey for England. In: Sheffield Uo, editor. *Health economics and decision science discussion paper series*; 2009. Sheffield, England.
49. Donaldson C, Baker R, Mason H. *European value of a quality adjusted life year*. final publishable report: SP5A-CT-2007-044172, [https://research.ncl.ac.uk/eurovaq/EuroVaQ\\_Final\\_Publishable\\_Report\\_and\\_Appendices.pdf](https://research.ncl.ac.uk/eurovaq/EuroVaQ_Final_Publishable_Report_and_Appendices.pdf)2010; 2010.

---

## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.puhe.2019.04.015>.