Journal of Pediatric Surgery 51 (2016) 853–858

Contents lists available at ScienceDirect

Journal of Pediatric Surgery

journal homepage: www.elsevier.com/locate/jpedsurg

Timing of bariatric surgery for severely obese adolescents: a Markov decision-analysis

Andrea M. Stroud [a,*], Devin Parker [b], Daniel P. Croitoru [c]

[a] The Dartmouth Institute of Health Policy & Clinical Practice, Geisel School of Medicine and Dartmouth Hitchcock Medical Center, Lebanon, NH
[b] The Dartmouth Institute of Health Policy & Clinical Practice, Lebanon, NH
[c] Section of Pediatric Surgery, Department of Surgery, Geisel School of Medicine, Children's Hospital at Dartmouth, Dartmouth Hitchcock Medical Center, Lebanon, NH

ARTICLE INFO

Article history:
Received 29 January 2016
Accepted 7 February 2016

Key words:
Obesity
Bariatric surgery
Adolescents
Gastric bypass
Decision analysis

ABSTRACT

Purpose: Although controversial, bariatric surgery is increasingly being performed in adolescents. We developed a model to simulate the effect of timing of gastric bypass in obese adolescents on quantity and quality of life.
Methods: A Markov state-transition model was constructed comparing two treatment strategies: gastric bypass surgery at age 16 versus delayed surgery in adulthood. The model simulated a hypothetical cohort of adolescents with body mass index of 45 kg/m^2. Model inputs were derived from current literature. The main outcome measure was quality and quantity of life, measured using quality-adjusted life–years (QALYs).
Results: For females, early gastric bypass surgery was favored by 2.02 QALYs compared to delaying surgery until age 35 (48.91 vs. 46.89 QALYs). The benefit was even greater for males, where early surgery was favored by 2.9 QALYs (48.30 vs. 45.40 QALYs). The absolute benefit of surgery at age 16 increased; the later surgery was delayed into adulthood. Sensitivity analyses demonstrated that adult surgery was favored only when the values for adverse events were unrealistically high.
Conclusions: In our model, early gastric bypass in obese adolescents improved both quality and quantity of life. These findings are useful for surgeons and pediatricians when counseling adolescents considering weight loss surgery.

Childhood obesity has been described as an epidemic and public health crisis in the Unites States (US), with 15–20% of children meeting criteria for obesity [1,2]. The population of severely obese youth, as defined by the Centers for Disease Control (CDC) as body mass index (BMI) ≥99th percentile between 1999 and 2004, is the most rapidly growing subgroup of obese children [3,4]. As of 2004, approximately 4% of US children were severely obese – in 1976, that fraction was less than 1% [4]. Severely obese youth are extremely likely to remain obese into adulthood, with consequent increased risk of cardiovascular disease, type 2 diabetes, hypertension, dyslipidemia, obstructive sleep apnea, and premature death [2,3]. Unfortunately, behavioral and pharmacological treatment approaches are rarely effective at achieving long-term weight loss [3,4]. For severely obese adolescents, who have failed medical approaches, there is a growing body of evidence demonstrating the safety and effectiveness of bariatric surgery [6–11].

However, there continues to be controversy surrounding bariatric surgery in adolescents. A recent survey of family physicians and pediatricians found that 48% of providers reported that they would never refer an obese adolescent for bariatric surgery [12]. Concerns stem from the immediate risk of operative complications and a lack of evidence demonstrating long-term benefit [13,14]. Critics of these procedures also cite moral and ethical concerns in an adolescent patient population, as well as age-specific medical concerns, such as future reproductive health and long-term effects of malabsorptive nutritional deficiencies [2,5,15]. On the other hand, some have suggested that it may be beneficial to perform bariatric surgery in adolescence, both decreasing the years spent at high BMI and reducing the operative risks associated with advanced obesity-related comorbidities [4]. Health and psychosocial benefits of bariatric surgery in adolescence would, therefore, be expected to exceed those of surgery delayed into adulthood. These controversies are increasingly relevant, given that bariatric surgery in adolescents has increased 3- to 5-fold between 1997 and 2003 [16,17].

Should adolescents be offered bariatric surgery? Although a randomized controlled trial comparing surgery during adolescence to delaying the decision into adulthood would be the most definitive way to answer this question, such a trial would require multiple decades of follow-up, if it were feasible at all. Families of, and clinicians who care for the growing population of extremely obese adolescents need to make decisions in the absence of such evidence. One way to obtain estimates of long-term outcome is through decision modeling techniques that incorporate information from multiple sources and vary input probabilities across realistic ranges. Therefore, we developed a Markov decision analysis model comparing the strategy of immediate gastric bypass surgery to that of delaying surgery into adulthood for severely obese adolescents, in order to estimate effects on quantity and quality of life.

* Corresponding author at: Division of General Surgery, Dartmouth-Hitchcock Medical Center, One Medical Center Drive, Lebanon, NH, 03756. Tel.: +1 608 698 0760; fax: +1 603 650 8086.
E-mail address: Andrea.M.Stroud@hitchcock.org (A.M. Stroud).

http://dx.doi.org/10.1016/j.jpedsurg.2016.02.036
0022-3468/

1. Methods

A Markov state-transition model was used to estimate the expected outcome of two possible management strategies for severely obese adolescents: immediate surgery in adolescence compared to delaying surgery into adulthood. Markov models are preferred over simple decision trees when decisions involve risk over time, when the timing of events are important, and when events may occur more than once, which all are possibilities in the lifetime of an adolescent bariatric surgery patient [18–21]. In a Markov model, patients' transition over time among different health states based on probabilities associated with the different interventions, and each health state has an associated quality of life [18]. Quality-adjusted life–years (QALYs) were used as a measure of the quality and quantity of life. QALYs take into account the quality of life lived in a particular health state, with a lower value assigned to a poorer health state [18]. QALYs value these health states by assigning "health utilities" or preference weights, which typically range from 0 (assumed equivalent to death) to 1 (equivalent to perfect health) [18].

1.1. Model overview

1.1.1. Patient population

The starting age of the patients in our model cohort was set at 16 years of age to coincide with the approximate average age reported in recent studies of adolescent bariatric surgery [6–11]. All patients were assumed to start with a BMI of 45 kg/m^2. We selected this average BMI, given that recent guidelines recommend a BMI ≥40 kg/m^2 for adolescent bariatric surgical candidates, and because most studies of adolescent gastric bypass surgery report an average BMI around 50 [6–11,22]. We chose the Roux-en-Y gastric bypass procedure, because it is the most commonly performed bariatric surgery in the US, accounting for 65–90% of cases [16,23].

1.1.2. Model structure

The Markov state-transition model compared Roux-en-Y gastric bypass surgery at age 16 to surgery delayed into adulthood. A medical management arm was not included in our model, as gastric bypass surgery has already been shown to improve life expectancy in adults [24,25]. A conceptual version of our model is shown in Fig. 1. In our Markov model, hypothetical cohorts of identical patients transition over time among different BMI categories and health states. In each one-year cycle of the model simulation, a small proportion of the cohort from each strategy dies according to age-, sex-, and BMI-specific mortality risks and mortality risk associated with gastric bypass surgery itself. The model simulation evaluated patients between ages 16 and 95 years.

Our model simulated two strategies: gastric bypass surgery as an adolescent (age 16) or delayed gastric bypass surgery as an adult. In the adult arm of the model, patients undergo surgery at age 35, and the adult surgery age was varied in a sensitivity analysis. In the immediate surgery arm, the patients in our simulation cohort face the initial risk of operative death and then distribute into three BMI-specific health states representing predicted post-surgical weight loss outcomes. Subsequent mortality risks are then predicted by their age-, sex- and post-surgical BMI. In the delayed surgery arm, the hypothetical cohort remains at their initial high BMI-specific health state until undergoing gastric bypass surgery at age 35. During this time they experience mortality rates predicted by their age, sex, and BMI. Following surgery, the adult surgery arm was modeled in a similar manner to that described above for the immediate surgery arm. For model development and computer simulated analyses, we used the software package TreeAge Pro 2014 (TreeAge Software, Inc., Williamstown, MA).

1.2. Model parameters and assumptions

For our base case we estimated gains in QALYs for a 16-year-old female with a BMI of 45 kg/m^2 undergoing gastric bypass surgery, since this could be considered an "average" surgical candidate. To form the basis for our model's assumptions, we conducted a comprehensive literature search with the assistance of a research librarian. We obtained information regarding basic components of the model: age-specific annual mortality rates based on sex and BMI, age-, sex-, and BMI-specific utilities, and surgical outcomes of mortality, weight loss, and surgical weight loss failure. We searched English-language,

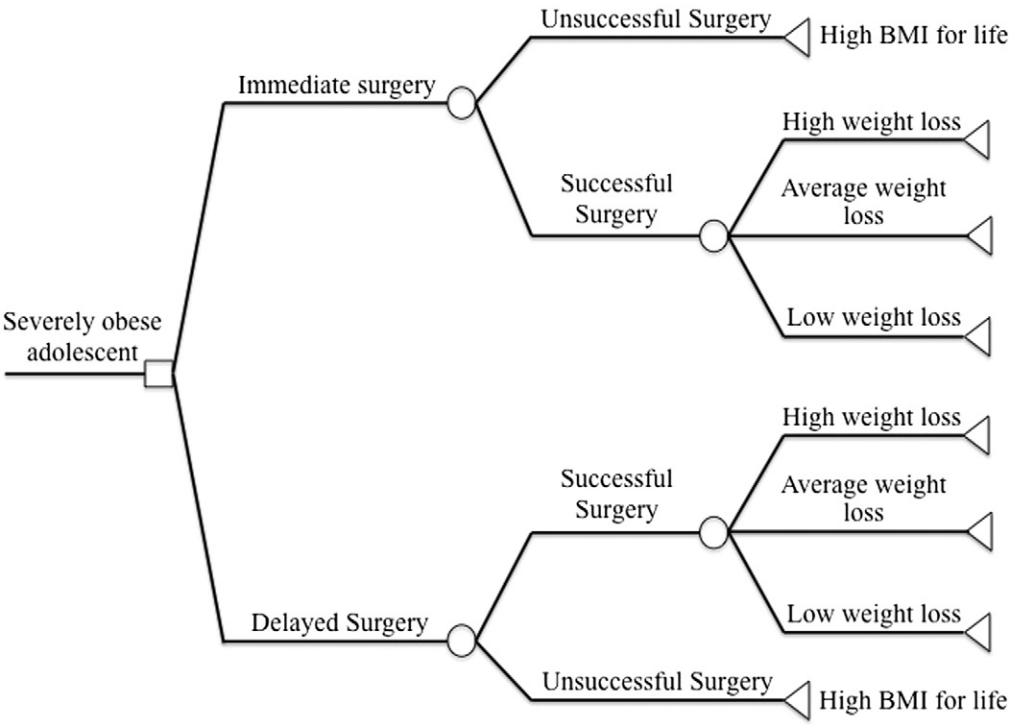

Fig. 1. Conceptual model. A Hypothetical cohort of obese adolescents' cycle through the model, beginning with the decision of immediate versus delayed gastric bypass surgery.