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REVIEW

A Review of Laparoscopic Sleeve Gastrectomy for Morbid Obesity

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Abstract Laparoscopic sleeve gastrectomy (LSG) is an innovative approach to the surgical management of morbid obesity. Weight loss may be achieved by restrictive and endocrine mechanisms. Early data suggest LSG is efficacious in the management of morbid obesity and may have an important role either as a staged or definitive procedure. A systematic review of the literature analyzing the clinical and operational outcomes of LSG was completed to further define the status of LSG as an emerging treatment modality for morbid obesity. Data from LSG were compared to benchmark clinical data and local operational data from laparoscopic adjustable gastric band (LAGB) and laparoscopic gastric bypass (LRYGB). Fifteen studies (940 patients) were identified following systematic review. The percent excessive weight loss (%EWL) for LSG varied from 33% to 90% and appeared to be sustained up to 3 years. The mortality rate was 0-3.3% and major complications ranged from 0% to 29% (average 12.1%). Operative time ranged from 49 to 143 min (average 100.4 min). Hospital stay varied from 1.9 to 8 days (average 4.4 days). The operational impact of LSG has not been described in the literature. According to data from the Royal Alexandra Hospital, the estimated total cost of LSG was $10,317 CAD as compared to LAGB ($7,536 CAD) and LRYGB ($11,666 CAD). These costs did not include further surgical interventions which may be required for an undefined group of patients after LSG. Early, non-randomized data suggest that LSG is efficacious in the surgical management of morbid obesity. However, it is not clear if weight loss following LSG is sustainable in the long term and therefore it is not possible to determine what percent of patients may require further revisional surgery following LSG. The operational impact of LSG as a staged or definitive procedure is poorly defined and must be analyzed further in order to establish its overall health care costs and operational impact. Although LSG is a promising treatment option for patients with morbid obesity, its role remains undefined and it should be considered an investigational procedure that may require revision in a subset of patients.

Keywords Laparoscopic · Sleeve gastrectomy · Morbid · Obesity

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Introduction

Obesity is a worldwide epidemic. Recent data show an increased prevalence of obesity in the adult and pediatric populations [1]. Globally, there are more than 1 billion overweight adults, at least 300 million of them obese [1]. The 2004 Canadian Community Health Survey: Nutrition documented 23.1% of Canadians aged 18 or older (approximately 5.5 million adults) with a body mass index (BMI) of 30 kg/m^2 or more. Using the World Health Organization classification of obesity [2], it has been shown that individuals in each obesity class are at increased risk of obesity-related illness as compared to those with a normal BMI (18.5-24.9) [3, 4]. Remarkably, cancer is the leading

cause of mortality in obese patients. Obesity accounted for as much as one in seven cancer deaths in men and one in five in women in the USA [5–7].

For patients with morbid obesity (obesity class II or III), surgical management remains the only evidence-based approach to achieving clinically important and sustainable weight loss [8]. In 1991, a National Institutes of Health Consensus Conference developed recommendations regarding the surgical management of obesity and established the current indications for surgery [9].

A minimally invasive approach to the surgical management of obesity has been shown to dramatically reduce perioperative morbidity through reduced blood loss, hospital stay, and wound complications [10]. Laparoscopic roux-en-Y gastric bypass (LRYGB) and laparoscopic adjustable gastric banding (LAGB) have become the most frequently performed bariatric procedures in the USA [11].

Laparoscopic sleeve gastrectomy (LSG) has recently been identified as an innovative approach to the surgical management of obesity. In this procedure, the greater curvature of the stomach is resected producing a narrow, tubular stomach with the size and shape of a banana (Fig. 1). This procedure has quickly attracted considerable surgical interest because it does not require a gastrointestinal anastomosis or intestinal bypass and it is considered less technically challenging than LRYGB. LSG also avoids implantation of an artificial device around the stomach in comparison to LAGB [12]. Weight loss following LSG is achieved by both restriction and hormonal modulation. Firstly, reduction in stomach size with the sleeve resection restricts distention and increases the patient's sensation of fullness (decreasing meal portion size). This restriction is further facilitated by the natural band effect of the intact pylorus which is maintained during the sleeve gastrectomy. Secondly, early evidence suggests a reduction in the hunger drive of patients undergoing sleeve gastrectomy. This may be related to decreasing serum levels of ghrelin, a hormone produced mainly by P/D1 cells lining the fundus of the human stomach which stimulates hunger [13].

LSG may be offered to patients as a definitive procedure for morbid obesity or as the first step in a staged surgical approach for patients with very high BMI (>60 kg/m^2). In the staged approach, following initial weight loss induced by LSG, surgical management may be completed by revising the LSG to a gastric bypass or a biliopancreatic diversion with a duodenal switch (Fig. 2). If a patient requires a secondary procedure following LSG (either planned or due to weight regain), analysis of clinical outcomes or operational impact (costs to healthcare system) of LSG should be cumulated and consider both procedures.

In this study, we analyzed the clinical outcomes and operational impact of LSG in a systematic review of the literature. Our aim was to understand if the best available evidence supports the use of LSG as a definitive procedure for morbid obesity and to determine the operational costs and resource impacts for LSG in a definitive or staged approach to morbid obesity.

Methods

A systematic review of the literature was performed for LSG. We searched for published or unpublished studies of LSG written in English prior to April 2009. The search strategy was applied to several electronic bibliographic databases including Medline (Pubmed search engine), Embase, Cochrane library, International Network of Agencies for Health Technology Assessment using the following key words: laparoscopic, endoscopic, minimally invasive surgery, LSG, vertical gastrectomy, partial gastrectomy, longitudinal gastrectomy, morbid obesity, obese, and overweight. Conference abstracts were also searched including Society of American Gastrointestinal Endoscopic Surgeons and American Society for Metabolic and Bariatric Surgery between 2000 and 2009.

Inclusion criteria for searches were: randomized controlled trials, non-randomized clinical trials, retrospective and prospective cohort studies, or case series. Studies were

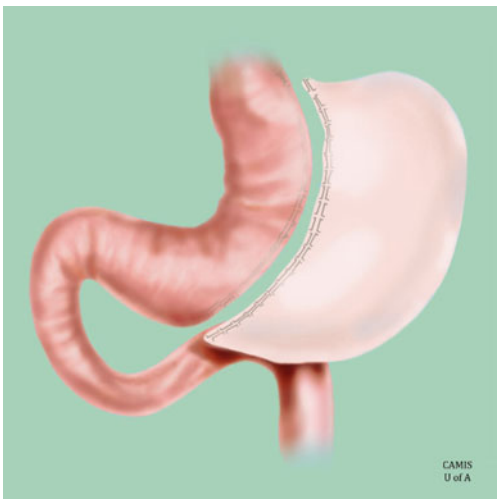

Fig. 1 Sleeve gastrectomy

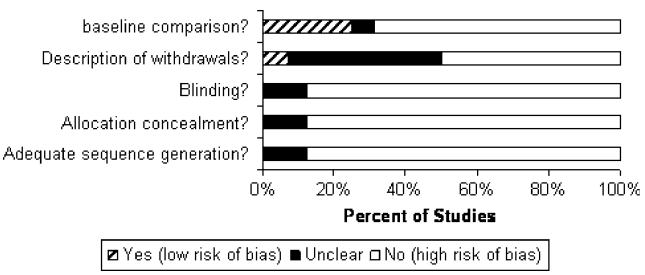

Fig. 2 Quality assessment of studies

included if they involved patients diagnosed with morbid obesity (BMI>40) or BMI between 35 and 40 with severe co-morbidities and underwent LSG. Studies were excluded if LSG was used for treatment of diseases other than morbid obesity, if investigators provided only surgical technique outcomes, or if follow-up was not reported.

Fifteen studies [14–28] were selected for review using the above search strategy. One study was one randomized control trials (study quality: grade B, level of evidence: 2b); six studies were retrospective and eight studies were prospective studies (grade C, level of evidence: 4) either with or without control groups.

A formal meta-analysis was not conducted in this review because of the high degree of heterogeneity among these studies. Eleven of 15 studies did not have a control group for comparison and the remaining five studies had different surgery procedures as comparing groups: three of them compared LSG with LAGB at 6 months, 2 years, and 3 years follow-up; the final two compared LSG with intragastric balloon and duodenal switch. Thus, it is not appropriate to undertake a statistical analysis based on the available evidence. Only descriptions of mean, range, and percentage were summarized and discussed in the review.

Results

We assessed the quality of these 15 selected studies; there were only one RCT with moderate risk bias and the remainder were controlled or case series studies with high risk of bias (Fig. 2).

We summarized data from 15 published studies (940 patients) describing short-term outcomes following LSG (see Appendix 1). These results were summarized in Table 1 and compared to the best available evidence for LRYGB and LAGB [29, 30]. One study was available that provided follow-up data up to 3 years; the remainder have a follow-up from 6 months to 2 years. Preoperative BMI ranged from 37.2 to 69 kg/m^2 and 28.8% of patients were male. Operative time ranged from 49 to 143 min with an average time of 100.4 min. Hospital stays were from 1.9 to 8 days, on average 4.4 days. The percent excessive weight loss (%EWL) ranged from 33% to 90% with follow-up from 6 months to 36 months. Comorbidity resolution 12-24 months after LSG had been reported in 365 patients (see Appendix 2). The data demonstrated rates of resolution and improvement of diabetes, hypertension, hyperlipidemia, degenerative joint disease, gastroesophageal reflux, peripheral edema, sleep apnea, and depression after LSG ranging from 45% to 95.3% and comparable to results of other restrictive procedures. One randomized trial was published which compared LSG to LAGB; results showed LSG at least as effective and durable as gastric banding at 1 and 3 years following surgery [21].

As with other procedures for bariatric surgery, perioperative risk for LSG appeared to be relatively low even in patients considered ‘high risk’. The overall reported mortality rate for LSG was 0.3%. Published complication rates ranged from 0% to 29% (average 11.2%). Some studies reported all minor complications (vomiting, nausea, and diarrhea) and others did not, confounding analysis. Major complications, such as staple line leakage and internal bleeding were summarized in Table 2.

Table 1 Summary of clinical outcomes of LSG as compared to LRYGB and LAGB

Outcomes	LAGB[a]	LRYGB[a]	LSG
Number of cases	3,374	3,195	940
Operative time (min)	77.5	164.8	100.4
Hospital stay (days)	1.7	4.2	4.4
%EWL (1 year)	37.8%	62.8%	59.8%
%EWL (2 year)	45.0%	54.4%	64.7%
%EWL (3 year)	55.0%	66.0%	66.0%
Comorbidity resolution	41-59%	65-84%	45-95.5%
Complications	6.50%	9.50%	12.1%
Mortality	0.47%	0.56%	0.3%

[a] LAGB and LRYGB references: [29, 30]

Costs

We were unable to identify published literature on the economic evaluation of LSG alone or in contrast to the

Table 2 Major peri-operation complications of LSG

Studies	Leakage	Hemorrhage
Arias 2009	0.7%	0
Nocca 2008	5.5%	0.6%
Lee 2007	1.4%	0
Melissas 2007	5.3%	15.8%
Cottame 2006	1.6%	0
Himpens 2006	0	2.5%
Langer 2006	0	0
Roa 2006	2.4%	3.3%
Silecchia 2006	0	4.9%
Baltasar 2005	0	6.5%
Han 2005	0.7%	0.7%
Milone 2005	0	5%
Mogno 2005	0	0
Almogy 2004	0	0
Regan 2003	0	14.3%
Mean±SD	1.17%±1.86%	3.57%±5.15%

LAGB or LRYGB. Given the important variation in techniques for bariatric surgery and varying use of endomechanical devices which greatly influence cost, we have reviewed the operational costs for LSG, LAGB, and LRYGB at our institution in order to understand the operational impact to healthcare. We identified 27 typical cases of LAGB, LRYGB, and LSG from three bariatric surgeons' patients for costing estimation. Data were obtained from the Royal Alexandra Hospital, Alberta Health Services and Alberta Medical Association. Mean operating times were used as a basis for determining human resource costs (i.e., assistant and anesthetist). Surgeon charges to Alberta Health and Wellness were referenced. For operating room costs, important features of the surgical techniques were included: disposable trocars used in all cases, ultrasonic dissection (harmonic scalpel) was used for dissection in LRYGB and LSG, the Swedish Adjustable Gastric Band® was used for LAGB, the Orvil technique was used for the RYGB, Peristrips dry® and Tisseel were used in the majority of LSG cases. Major device and endomechanical costs were itemized in Table 3.

An estimate of the overall costs of LSG when used in a staged surgical approach for high-risk or high BMI patients would include the total costs of LSG and a secondary procedure (i.e., for LRYGB as the secondary procedure total costs would be $10,142+$11,477= $21,619).

Discussion

If current trends in the prevalence of obesity persist by 2010, 27% of Canadian men and 24% of Canadian women will be obese [31]. In 2004, one in four (26%) Canadian children and adolescents aged 2–17 years were overweight. The obesity rate has increased dramatically in the last 15 years: from 2% to 10% among boys and from 2% to 9% among girls [32]. The total direct healthcare cost of obesity in 2001 was estimated to be over $1.6 billion, which corresponded to 2.2% of the total health care expenditures for all diseases in Canada [33]. Bariatric surgery is the only evidence-based approach to sustainable weight loss and by improving comorbid disease and survival, healthcare costs after bariatric surgery (RYGB) are recovered in approximately 3 years.

LSG is an innovative procedure for the management of obesity. It was originally developed as a first-stage bariatric procedure to reduce surgical risk in high-risk patients through the induction of dramatic weight loss. Analysis of the literature suggests LSG is efficacious in the short term and may offer certain advantages when compared to the existing options of LAGB and LRYGB. These advantages include: technical efficiency, lack of an intestinal anastomosis, normal intestinal absorption, no risk of internal hernias, no implantation of a foreign body, pylorus preservation (prevents dumping syndrome), and finally LSG may be considered the most appropriate option in extremely obese patients [22]. Moreover, the entire upper gastrointestinal tract remains accessible for endoscopic assessment. Concerns remain however, regarding the risks and important major complications associated with LSG including staple line leak (1.17%), post-operative hemorrhage (3.57%), and the irreversibility of LSG.

With respect to the evidence on the various technical aspects of performing LSG, there is currently no consensus

Table 3 Operational costs of LSG vs. LRYGB and LAGB

	LAGB (n=9)	LRYGB (n=9)	LSG (n=9)
Anesthesia	$204	$641	$523
Assistant	$589	$605	$432
Surgeon	$1,032	$2,615	$1,075
Endomechanicals:			
Trocars	$323	$335	$316
Staplers	-	$2,998	$2,021
Ultrasonic Dissector	-	$713	$713
Peristrips	-	-	$2,525
Tisseel	-	-	$749
SAGB	$4,500	-	-
Orvil Stapler	-	$967	-
All other	$354	$1,385	$654
Hospitalization ($485/day)	$534	$1,407	$1,310
Total	$7,536	$11,666	$10,317

Costs were based on mean operative time: 43 min LAGB, 135 min LRYGB, 110 min LSG; LOS: 1.1 day LAGB, 2.9 day LRYGB, 2.7 day LSG (Royal Alexandra Hospital, June 2008-June 2009)

and standardization of the technique. Specifically, regarding bougie size, there may be a trend towards a smaller caliber sleeve. Between 2003 and 2006, bougie sizes ranged from 32 to 60 Fr, while from 2007 to 2009 sizes varied only from 32 to 40 Fr. The evidence suggests a smaller bougie size may result in greater weight loss and may prevent later stretch of the sleeve. The operational impact and total healthcare costs for LSG are poorly defined. Our analysis suggests that LSG may be costly, especially in a staged surgical approach to obesity. Further, as a staged procedure, LSG will require experienced bariatric surgeons with advanced laparoscopic skills to complete the second stage procedure safely and efficiently. The overall time to recoup costs for LSG as compared to LRYGB has not been determined and warrants further analysis.

Medium-term clinical outcomes for LSG will emerge in the very near future, however, long-term (>10 years) weight loss and co-morbidity resolution data for LSG will remain undefined for several years. Weight regain or a desire for further weight loss in a super-obese patient may require revision to a gastric bypass or biliopancreatic diversion. Surgeons and patients considering LSG should be fully informed of the limitations of current data.

Conclusion

Early, non-randomized data suggest that LSG is efficacious in the surgical management of morbid obesity. It is not clear if weight loss following LSG is sustainable in the long term. Until such outcomes are obtained from high quality studies, the role of LSG in the surgical management of obesity remains undefined and it should remain as an investigational procedure. The operational impacts of LSG as a staged or definitive procedure are poorly defined and must be analyzed further.

Conflict of interest disclosure The authors declare that they have no conflict of interest.

Appendix 1

Table 4 Summary of included studies

Author	Year	Country	Design	Patient no.	Male	Age	LOS	OR time (min)	Pre operative BMI	Follow-up (year)	Post operative BMI	%EWL	Complication	Bougie (Fr)	Mortality
Arias [14]	2009	USA	Retrospective	130	36	45.6	3.2	97	43.2	2	27.1	67.9% (62.2% 1 year)	9.8%	40	0
Nocca [15]	2008	France	Prospective	163	52	41.6	8		45.9	2		61.5% (59.5% 1 year)	7.4%	36	0
Lee [17]	2007	USA	Retrospective	216	43	44.7	1.9	66	49	1	27.7	59%	6%	32	0
Melissas [16]	2007	Greece	Prospective	23	7	38.9			47.2	1	31.1		21.7%	34	0
Cottam [22]	2006	USA	Retrospective	126	59	49.5	3	143	65.3	1	49	46%	14%	46–50	0
Himpens [21]	2006	Belgium	RCT	40	9	40			39	3		66% (57.7% 1 year)	5%	34	0
Langer [20]	2006	Austria	Prospective	23	6	41.2			48.5	1.5		56%	4%	48	0
Roa [19]	2006	Korea	Retrospective	30	7	40	3.2	80	41.2	0.5	32	53%	13%	60	0
Silecchia [18]	2006	Italy	Prospective	41	13	44.6	5.7	111	57.3	1	40.8		12%	48	0
Baltasar [26]	2005	Spain	Prospective	7 7 16			2	49	61–74 >40 35–43	27 months 16 months 27 months		56.1% 33.6–90% 62.3%	6.70%	32	3.3%
Han [23]	2005	Korea	Retrospective	60	8	30			37.2	1	28	83.3%		48	1.7%

Table 4 (continued)

Author	Year	Country	Design	Patient no.	Male	Age	LOS	OR time (min)	Pre operative BMI	Follow-up (year)	Post operative BMI	%EWL	Complication	Bougie (Fr)	Mortality
Milone [25]	2005	USA	Retrospective	20	13			114	69	0.5	53	35%	5%	60	0
Mogno [24]	2005	France	Prospective	10	5	43	7.2	120	64	1	41	51%	0	32	0
Almogy [27]	2004	USA	Retrospective	21	9	44	7		57.5	1.5		61%	23.8%		0
Regan [28]	2003	USA	Retrospective	7	4	43	2.7	124	63	11 months	50	33%	29%	60	0
Mean± SD				940[a]	271[a]	42± 4.6	4.4± 2.3	100.4± 30	52± 10.6	1.4±0.7			12.1%± 8.1%	43.7± 10.9	
Range						30–49.5	1.9–8	49–143	37.2–69	0.5–3	27.1–53	33–90%	0–29%	32–60	0–3.3%

[a] Total number

Appendix 2

Table 5 The improvements of comorbidities after LSG

	Cottam (2006) [22]	Han (2005) [23]	Milone (2005) [25]	Silecchia (2006) [18]	Average R+I
Patients	126	60	20	41	247
Follow-up	1 year	1 year	6 months	18 months	6–24 months
Type 2 diabetes	81%R 11%I	100%R	30%I	79.6%R 15.4%I	77.2%
Hypertension	78%R 7%I	93%R 7%I	55%I	62.5%R 25%I	71.7%
Hyperlipidemia	73%R 5%I	45%R 30%I	30%I	–	61%
Sleep apnea	80%R 7%I	100%R	60%I	56.2%R 31.2%I	83.6%
Degenerative Joint disease	85%R 6%I	76%R 24%I	95%I	–	95.3%
Gastro- esophageal Reflux	70%R 8%I	80%R 20%I	25%I	–	67.7%
Peripheral Edema	91%R 3%I	–	–	–	94%
Depression	67%R 9%I	–	14%I	–	45%

R resolved; *I* improved

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