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REVIEW ARTICLE

The Effects of Bougie Caliber on Leaks and Excess Weight Loss Following Laparoscopic Sleeve Gastrectomy. Is There an Ideal Bougie Size?

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Abstract Laparoscopic sleeve gastrectomy (LSG) has become a common surgical procedure, yet there is no consensus on what bougie size is best for LSG. We reviewed the literature and assessed the relationship between the size of bougie used and the incidence of leak as well as weight loss parameters. We wanted to determine if there is an ideal bougie size for LSG. A search of the medical literature was undertaken. We limited the search to articles published in the last 5 years written in English and investigating humans. We analyzed 32 publications comprising 4,999 patients. We determined the frequency of staple line leaks as well as weight loss parameters in relation to bougie size. This study was exempt from our institutional review board. The use of bougies of 40 French (F) and larger was associated with a leak rate of 0.92 % as opposed to 2.67 % for smaller bougies ($p<0.05$). Weight loss in percent of extra weight loss (%EWL) was 69.2 % when a bougie of 40 F and larger was used, as opposed to 60.7 % of EWL when smaller bougies were used ($p=0.29$). LSG is becoming an important and common procedure. Larger sizing bougies are associated with a significant decrease in incidence of leak with no change in weight loss. Further studies are needed before an unequivocal decision on the optimal bougie size is made. A recommendation to use the smallest bougie possible should be avoided because the risks may outweigh the benefits.

Keywords Sleeve · Gastrectomy · Bougie · Leak · Regain · Excess · Weight · Loss

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Introduction

Laparoscopic sleeve gastrectomy (LSG) has become a common surgical procedure aimed at treating morbid obesity and its associated comorbidities. This restrictive bariatric procedure involves longitudinal resection of the greater curvature of the stomach around a sizing bougie, thereby creating a small-volume tubular stomach based on the lesser curvature. Initially LSG was used as a first-stage operation in severely morbidly obese patients to achieve some weight loss and lower the morbidity rate prior to more complex and definitive procedures. These patients showed marked weight loss and drastic improvement in comorbidities after undergoing LSG alone [1]. Today, LSG is a stand-alone procedure.

LSG has a risk profile and effectiveness that are between laparoscopic gastric banding and Roux-en-Y gastric bypass [2]. One of the major postoperative complications of LSG is staple line leak, which occurs in approximately 2.5 % of patients and can sometimes result in death [3]. There are various factors which influence the risk of leak. One suggested risk factor may be the size of the bougie used in the procedure. Aurora et al. found that use of bougies with diameter >40 French (F) resulted in decreased instances of staple line leakage compared to use of bougies with diameter <40 F [3]. Still, there is no evidence-based consensus on the optimal size of the bougie to be used when calibrating the final volume of the stomach after resection [4]. In the international sleeve gastrectomy expert panel consensus (held during March 2011 in Florida, USA), 87 % of participants thought the optimal bougie size was between 32 and 36 F [5]. It seems that using bougies of this size is somewhat of a trend and is not evidence based. Some authors believe that using a larger bougie may be detrimental to the efficacy of weight loss or may entail a regain in weight do to eventual dilatation of the stomach. Atkins et al. demonstrated that patients who underwent LSG with sizing bougies of 40 F diameter showed better results of weight loss and resolution of comorbidities compared to those patients who underwent

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surgery using 50-F bougies with a follow-up period of 48 months [6].

Thus, is seems that there is a rationale for both favoring smaller bougie size, in order to increase weight loss, and also favoring greater bougie size, in order to decrease leak rates. In this study, we reviewed the medical literature in order to assess the effect of bougie size on staple line leaks and on loss of excess body weight. Our aim was to gather a wide dataset and generate an analysis which could guide bougie size decisions for LSG.

Methods

We performed a search of the electronic medical literature on LSG and its morbidities. We used the keywords "laparoscopic sleeve gastrectomy" which resulted in a total of 346 articles. We limited the search for articles published in the last 5 years (2008 to 2012) written in English and investigating humans. This yielded 233 articles which we reviewed. We excluded publications dealing with special subpopulations, investigating specific biochemical endpoints and withholding information on leak rates or the size of sizing bougie that was used. We also excluded studies based on retrospective surveys and those demonstrating novel surgical techniques. We ended up with a final pool of 32 articles covering a total of 4,999 sleeve gastrectomy procedures [7–38].

Our aim was to assess weight loss and leak rates in relation to the size of the calibrating bougie. The data we collected were initial body mass index (BMI), bougie size, percent of excess weight loss (%EWL), percent of excess BMI loss (%eBMIl), leak rate, and in those publications having long-term follow-up, regain of %EWL. In the publications which reported using several sizes of bougies, we calculated the average bougie size.

In our analysis, we compared outcomes (%EWL and leak rates) between studies with average bougie size lower than 40 F versus those with bougie size equal to or higher than 40 F. In this analysis, continuous variables were compared with Student's *t* test or with the Mann–Whitney test for nonparametric distributions. We also assessed the association of bougie size with %EWL and leak rates using average bougie size as a continuous variable. For this analysis, we calculated the Pearson correlation coefficient (or Spearman correlation coefficient for nonparametric data). In all analyses, a two-tailed *p* value of 0.05 or less was considered statistically significant.

Results

In our search of the literature, we found 346 publications. After limiting our search to 2008 onwards, we were left with 233 articles. Following subsequent exclusions, we were left with 32 publications (Fig. 1) which were incorporated in this report, describing a total of 4,999 sleeve gastrectomy laparoscopic procedures [7–38]. Bougie size varied between 28 and 60 F. In three studies, an endoscope was used to calibrate the diameter of the gastric sleeve instead of a bougie [7, 11, 30]. The mean preoperative BMI ranged between 37.4 and 54.9. All publications reported percentage of leaks which ranged from 0 to 8.9 %. A total of 104 (2 %, 95 % CI 1.7 to 2.5 %) patients suffered gastric leaks. Most authors recorded weight loss by %EWL, three publications recorded weight loss by %eBMIl, four publications did not mention any follow-up of weight loss, and three publications only recorded mean final BMI. We chose not to distinguish between %EWL and %eBMIl in our analysis because in most patient populations, they are closely approximated. These parameters for weight loss ranged between 33 and 86.6 %. Table 1 lists the included studies, leak rates, EWL, and average bougie size.

There were 26 studies with average bougie size lower than 40 F, with 3,307 patients, while six studies had an average bougie size equal to or larger than 40 F, with 1,692 patients. Studies of either group were published during the same time period, and the lengths of follow-up were similar. In Table 2, we present a comparison between the studies of average BMI prior to LSG, maximum %EWL, and leak rates. Studies were similar in the BMI profile of the included patients and in the maximum %EWL. However, studies with the larger bougie size demonstrated a lower leak rate. When limiting the analysis only to studies which measured true %EWL (excluding studies which reported %eBMIl), the results were similar, with studies of the smaller bougie size reporting a mean (average) 2.8 % (1.4 %) leak rate and studies with larger bougie size reporting a 0.46 % (0.4 %) leak rate (*p* value=0.001). Analyses using 38 F as the cutoff generated similar results. Mean follow-up for both groups was around 20 months (Table 2). Ideally, a longer follow-up is needed to draw conclusions about the efficacy of weight loss. Unfortunately, there are currently not enough published studies with long follow-up for such an analysis.

Assessing a linear relationship between average bougie size and leak rate did not reveal a significant association, nor did the correlation between bougie size and max %EWL (Fig. 2). There was no significant association between weight loss and leak rate, though there seems to be a negative association (Fig. 3).

Only a handful of studies had long enough follow-up to detect any regain. Furthermore, regain is very much dependent on the time elapsed from the procedure. Too few studies had overlapping periods of time of follow-up to seriously address the question of the effect of bougie size on regain. We therefore decided not to analyze regain as a factor of bougie size until there are more studies with longer follow-up.

Discussion

Staple line leak is one of the major postoperative complications of LSG, causing significant morbidity and mortality.

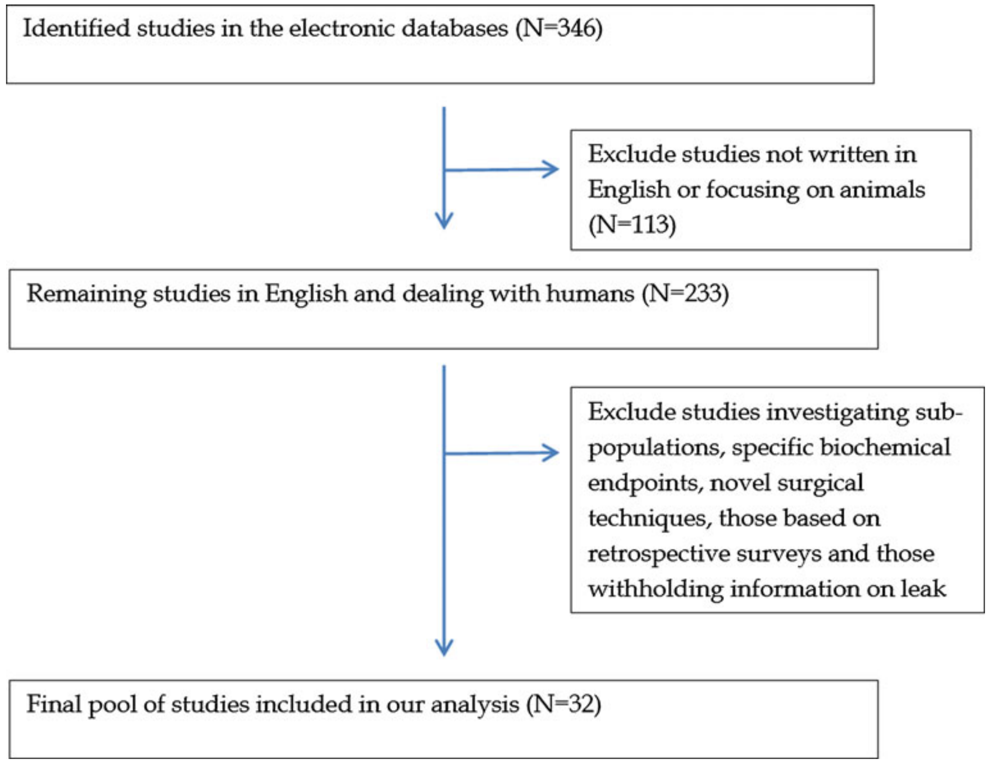

Fig. 1 Flow chart of literature search

Previous reviews of the literature have shown the rate of this complication to be around 2.5 % on average, and individual case series have shown leakage rates between 0 and 8.9 %. The most common location of staple line leaks is in the area of the gastroesophageal junction (GEJ). Possible causes of leaks at this site may be imperfect technique or technical malfunction of the stapler device. These leaks, however, occur even in the hands of experienced surgeons, and over sewing the stapler line did not show any decrease in the leak rate ([39], buttressing does lower incidence of leak). Therefore, we believe that the reason for a leak in this area is probably multifactorial and includes relative ischemia and increased wall tension. The arterial supply of the new gastric tube is based on the left gastric artery with multiple branches reaching the staple line and sometimes causing bleeding from the edges following stomach resection. The fundus just lateral to the cardiac notch, however, is left relatively avascular following resection because normally, this area is supplied by the short gastric arteries.

Additionally, according to Le Place's law, the wall tension is proportionate to the product of the radius and pressure. The sleeve resection is usually carried out adherent to the bougie in the stomach body, but as the line of resection reaches the esophagus, there is a tendency to move away from the GEJ to avoid injuring this area and to perform the resection on a structure with serosal lining rather than including the esophageal wall. Therefore, the proximal area of the neo-stomach is usually wider, has a larger diameter, and thereby has increased wall tension which might be susceptible to staple line separation.

The diagnosis of postoperative leaks is made by both clinical and radiological evidence. The cardinal sign of leakage is tachycardia [19], which can be accompanied by fever, epigastric pain, leukocytosis, and elevated C-reactive protein [28]. Additionally, postoperative water-soluble contrast material swallow or computerized tomography with oral contrast may show extravasation of contrast material from the stomach.

Staple line leaks can be classified according to their location as proximal or distal. Additionally, leaks can be classified into three groups according to the time of diagnosis [40]: those detected from postoperative day (POD) 0 to POD 3 (POD −3), those detected between POD 4 and POD 7 (POD 4–7), and those occurring after POD 7 (POD +8). These classifications are important because both the location and timing of leakage influence the management of this complication. It is generally agreed that it is best to avoid surgical intervention after POD 4. There is also increasing evidence that proximal leaks are more amenable to intraluminal stenting [19].

It has recently been shown that using larger sizing bougies in LSG can reduce the incidence of staple line leaks [3]. This can also be seen in our analysis of the current literature. Using larger bougies of 40 F and higher is associated with a relative risk reduction of 66 %. This is a substantial decrease of one of the most debilitating and dangerous complications of LSG.

Some authors have argued that larger bougies may cause decreased weight loss and increased regain. We found no statistically significant difference in weight loss (measured in maximum %EWL) between the group of studies using bougies of 40 F and higher and the group using bougies smaller than

Table 1 Publications regarding bougie size and leaks (in order of increasing bougie caliber)

	Author	Year	Average bougie size	Number of participants in the study	Average BMI	EWL at 12 months	Leak %	Leak *N*	Follow-up in months
1	Diamantis	2010	29	25	53.5	60.80 %	0.00 %	0	12
2	Frezza	2008	33.5	53	53.5	52.20 %	3.70 %	2	18
3	D'Hondt	2011	30	83	39.3	81.51 %	0.00 %	0	72
4	Stroh	2009	32	144	54.5	na	7.00 %	10	na
5	Ser	2010	32.7	118	37.6	81.50 %	3.39 %	4	24
6	Fuks	2009	34	135	48.8	49.40 %	5.10 %	7	12
7	Bellanger	2011	34	529	44.26	65.92 %	0.00 %	0	36
8	Chopra	2012	34	185	48.97	55.52 %	2.16 %	4	36
9	Kueper	2008	34	16	49.1	na	0.00 %	0	6
10	Nath	2010	34	100	46.4	na	1.00 %	1	6
11	Behrens	2011	35	34	50.3	37.80 %	2.94 %	1	12
12	Burgos	2009	35	214	37.8	na	3.27 %	7	na
13	Jurowich	2011	36	45	54.9	na	8.90 %	4	na
14	Skrekas	2008	36	93	46.86	67.21 %	4.30 %	4	18
15	Nocca	2008	36	162	45.9	59.45 %	3.66 %	6	24
16	Chowbey	2010	36	75	58	59.13 %	0.00 %	0	24
17	Prasad	2012	36	108	44.5	67.50 %	0.00 %	0	24
18	Sammour	2010	36	100	50.3	62.90 %	3.00 %	3	12
19	Srinivasa	2010	36	253	50	59.00 %	2.37 %	6	12
20	Slater	2011	36	22	46	56.00 %	4.54 %	1	12
21	Kasalicky	2008	38	61	41.8	na	0.00 %	0	18
22	Csendes	2010	38	343	37.5	na	4.66 %	16	na
23	Lee	2011	38	30	42.6	na	0.00 %	0	6
24	Mui	2008	38.1	70	40.7	63.50 %	1.43 %	1	12
25	Menenakos	2009	38	261	45.2	65.70 %	3.80 %	10	24
26	Ramalingam	2011	38	48	42.5	49.60 %	4.17 %	2	12
27	Arias	2009	40	130	43.2	62.20 %	0.70 %	1	24
28	Basso	2011	48	200	45.5	BMI 30.6	2.50 %	5	18
29	Felberbauer	2008	48	126	48.09	na	1.59 %	2	18
30	Rubin	2008	48	120	43	53.10 %	0.00 %	0	12
31	Gill	2012	50	116	44	na	0.00 %	0	12
32	Boza	2012	60	1,000	37.4	86.60 %	0.70 %	7	36

Author primary author, *Year* year published, *F* French, *BMI* mean preoperative body mass index, *EWL* extra weight loss, *Leak %* percent of participants who suffered from gastric leak, *Leak N* number of participants who suffered from gastric leak, *na* information not available

Table 2 Leak rates and weight loss in %EWL according to bougie caliber

	Bougie size smaller than 40 F	Bougie size equal to or greater than 40 F	*p* value
n	26	6	–
Average BMI	46 (5.7)	43 (3.5)	0.22
Max %EWL	60.7 % (12.3 %)	69.2 % (16.8 %)	0.29
Leak rate	2.67 % (2.38 %)	0.92 % (0.97 %)	0.01
Follow-up, months	19.4 (14.5)	20 (9)	0.95

40 F. Both groups had similar initial BMI and length of follow-up. There was not enough data to assess the effect on regain.

What is the ideal bougie size for LSG? The significance of this question is ever more relevant due to the growing popularity of LSG as a single-step weight loss procedure. From our point of view, it seems that the advantage of a dramatic decrease of leak rate with no difference in weight loss favors using larger-caliber bougies in LSG. Staple line leaks are associated with significant morbidity and mortality. Although the rates of leakage are not very high, they are difficult to treat, require long hospitalization course, cause substantial discomfort to patients, and if not diagnosed in time may result in death.

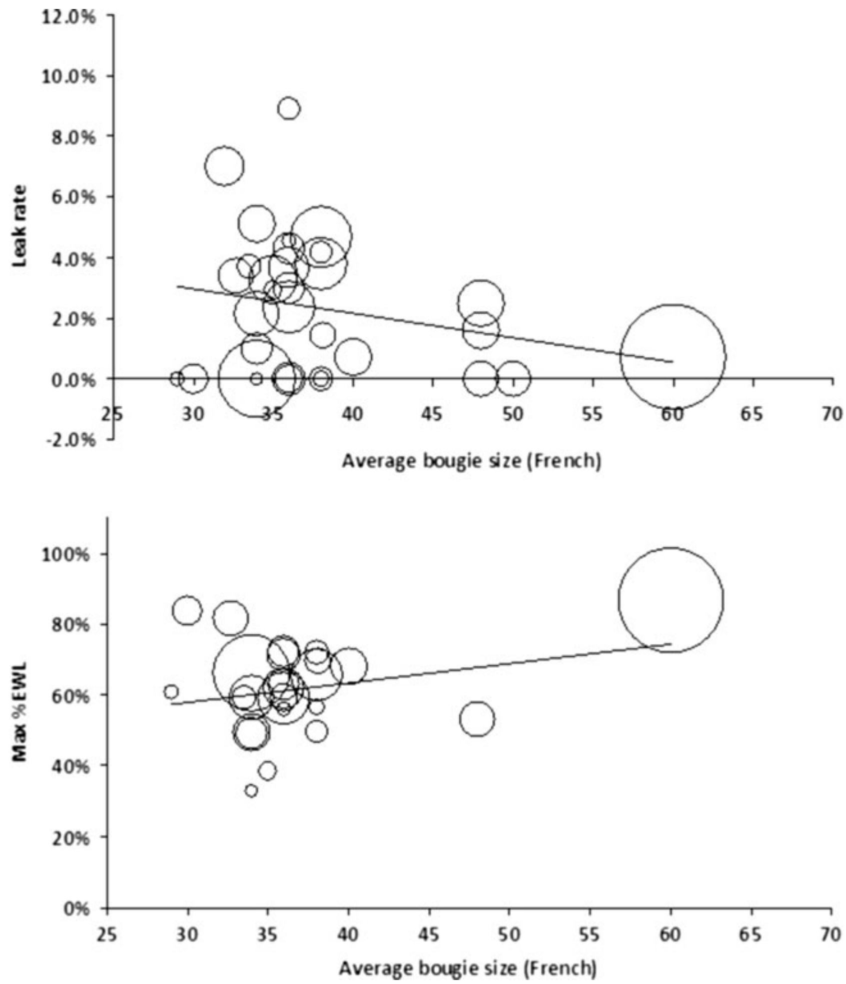

Fig. 2 *Top panel*—leak rates as a function of average bougie size per study. The *line* depicts linear regression correlation: $r=-0.23$, p value=0.4. *Lower panel*—maximum percent of estimated weight loss as a function of average bougie size per study. The *line* depicts linear regression correlation: $r=0.26$, p value=0.14. In both *panels*, each *circle* depicts study and its size

Our study has several inherent limitations: the analysis and pooling of study estimates required an ecological analysis. Patient-centered outcome research should follow our results in order to provide more reliable evidence. The studies included in this analysis were most often dedicated center experiences, thus patient selection was not standardized, nor were protocol for the diagnosis of leakage. Certainly, there exists far greater real-life experience than the accumulation of published procedures, and

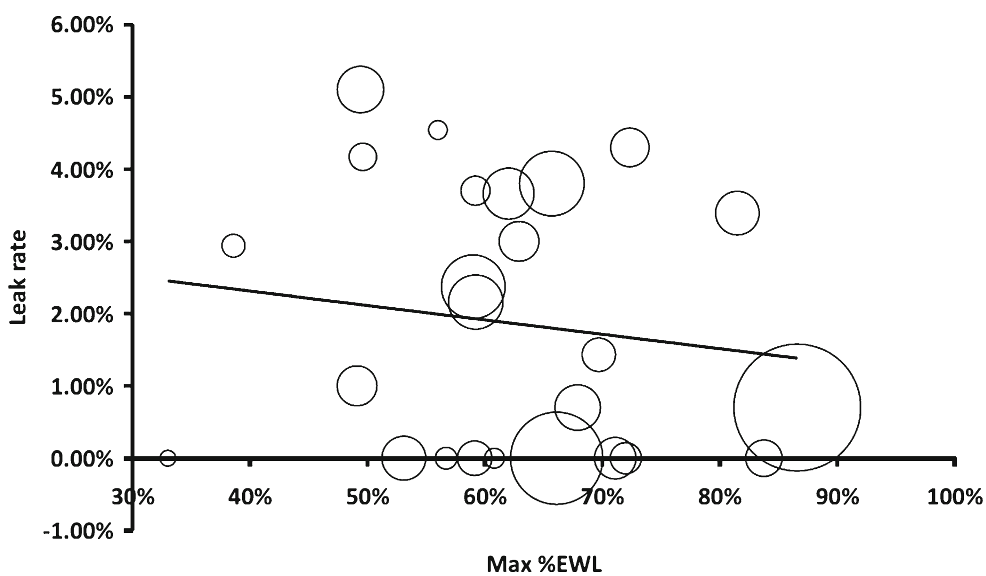

Fig. 3 Leak rates as a function of maximum percentage of estimated weight loss. The *line* depicts linear regression correlation: $r=-0.29$, p value=0.2. Each *circle* depicts a study and its size

publication bias is to be expected. Due to the popularity and significant role of LSG in the management of obesity and related morbidities, there is a clear need for high-quality, multi-institutional clinical trials, designed to identify the most efficacious procedures.

In this review of the literature, we looked specifically at weight loss parameters and leakage rates since we believe the two are affected by bougie size. We did not take into account other complications of LSG such as bleeding and stricture. It is possible that other complications are also dependent on the size of the bougie used. Nevertheless, a sweeping recommendation to use the smallest bougie possible as a default should be avoided because the risks may outweigh the benefits.

Conflict of Interest All the authors have nothing to disclose.

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