Left Gastric Artery Embolization in Obese, Prediabetic Patients: A Pilot Study

Mohamed M.A. Zaitoun, MD, Mohammad Abd Alkhalik Basha, MD, Farouk Hassan, MD, Saeed Bakry Elsayed, MD, Alaa A. Farag, MD, Mahmoud Amer, MD, Sameh Abdelaziz Aly, MD, and Nahla Zaitoun, MD

ABSTRACT

Purpose: To evaluate the effect of left gastric artery embolization (LGAE) on glycated hemoglobin (HbA1c) in a prospective obese, prediabetic cohort.

Materials and Methods: This prospective pilot study included 10 obese, prediabetic patients (7 females and 3 males; mean age 37.5 ± 8.8 years; range 28–51 years) admitted to the Interventional Radiology Unit between January 2017 and June 2018 for LGAE for weight reduction. The main inclusion criteria were body mass index (BMI) >30 kg/m² and HbA1c ranging from 5.7 to 6.4. Body weight, BMI, and HbA1c were assessed for each patient preprocedure and at 6 months postprocedure. Statistical analysis was performed using a paired sample t test.

Results: The baseline mean body weight, BMI, and HbA1c were 107.4 ± 12.8 kg, 37.4 ± 3.3 kg/m², and 6 ± 0.2, respectively. Concerning complications, no serious adverse events were detected. Six months after the procedure, the mean body weight and BMI significantly decreased to 98 ± 11.6 kg and 34.1 ± 3 kg/m², respectively (P < .0001). A paired sample t test showed a significant reduction in HbA1c from pre- to postprocedure (6.1 ± 0.2 preprocedure vs 4.7 ± 0.6 postprocedure, P < .0001). The mean percent reductions in body weight, BMI, and HbA1c were 8.9% ± 1.2, 8.8% ± 1, and 21.4% ± 8.9, respectively. A statistically significant positive correlation was found between BMI and HbA1c after the procedure (r = 0.91, P = .0002).

Conclusions: LGAE is well tolerated and leads to clinically significant decreases in weight and HbA1c in obese, prediabetic patients.

ABBREVIATIONS

AE = adverse event, BMI = body mass index, DSA = digital subtraction angiography, HbA1c = glycated hemoglobin, LGA = left gastric artery, LGAE = left gastric artery embolization

Prediabetes and diabetes are generally manifestations of a much broader underlying disorder, including metabolic syndrome, a highly prevalent, multifaceted condition characterized by a group of abnormalities that include abdominal obesity, hypertension, dyslipidemia and elevated blood glucose (1). Diabetes is characterized by hyperglycemia resulting from defects in insulin secretion, insulin action, or both. The diagnostic criteria of diabetes are fasting plasma glucose ≥7.0 mmol/L, random plasma glucose ≥11.1 mmol/L, and glycated hemoglobin (HbA1c) ≥6.5% (2). Prediabetes is characterized by a blood glucose level that does not fulfill the criteria for diabetes diagnosis, but is too high to be assessed as normal. Prediabetic patients have HbA1c values ranging from 5.7 to 6.4 (3,4). A reduction in HbA1c is accepted as a well-validated marker for glycemic control and has become the standard outcome measure in many trial models for a myriad of diabetes therapies (5). Prediabetes is closely related to obesity, especially visceral (abdominal) obesity (6). A 7% reduction in weight is thought to decrease the risk of diabetes occurrence in the prediabetic population and delay the progression from a prediabetic state to type 2 diabetes (7,8).

Several international studies have discussed the health benefits of bariatric procedures in diabetic patients. Laparoscopic sleeve gastrectomy in diabetic patients with obesity may be efficient for obtaining optimal glycemic control (9–13). Nevertheless, a few other studies documented that...
The study is a single-center, prospective pilot study investigating the effect of left gastric artery embolization (LGAE) on glycosylated hemoglobin (HbA1C) levels in a cohort of obese, prediabetic patients.

Ten subjects with mean body mass index (BMI) of 37.4 ± 3.3 and mean HbA1C of 6.0 ± 0.2 were enrolled between 2017 and 2018. Study participants were treated with LGAE using 300–500 μ particles injected to an angiographic stasis end point. They were not provided other dietary, exercise, or pharmacological measures for diabetic control. The primary study outcome measure was HbA1c reduction at 6 months postprocedure.

The major study findings included a statistically significant reduction of HbA1c levels to 4.7 ± 0.6 (21.4% reduction) at 6 months postprocedure (P < .0001), which was associated with a statistically significant reduction in BMI to 34.1 ± 3.0 (8.8% reduction, P < .0001) at the same time point. Adverse events were limited to mild epigastric pain in 70% of patients.

The study findings suggest that LGAE results in meaningful decreases in HbA1c and BMI in obese, prediabetic patients. It indicates that this treatment approach merits further exploration in larger cohorts with comparison to untreated controls.

Bariatric surgery may not be associated with optimal glycemic control (14–16).

Left gastric artery embolization (LGAE) is now considered a promising technique for weight loss (17,18). The literature includes many clinical trials that were performed to evaluate the role of LGAE in weight loss in humans and the results were highly encouraging (19–23).

Despite bariatric procedures having been confirmed to improve patient clinical outcomes by reducing the risk of potential weight-related health problems, to date, the effectiveness of bariatric embolization has not been adequately studied in patients with diabetes and those with prediabetes. Results from only a single diabetic patient participating in GET LEAN trial have been reported (20); hence, studies would be of international interest. Accordingly, we conducted this pilot study to explore the effects of LGAE on weight loss and changes in HbA1c in obese, prediabetic patients. Our hypothesis is that a statistically significant reduction in weight loss and HbA1c occurs over a 6-month period after LGAE among obese patients with prediabetes.

MATERIALS AND METHODS

Study Design
A single-arm prospective cohort study was conducted in a group of obese, prediabetic patients seeking weight loss by LGAE.

Table 1. Baseline Demographic Data

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Sex</th>
<th>Age</th>
<th>Weight, kg</th>
<th>Height, m</th>
<th>BMI, kg/m²</th>
<th>HbA1c</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>33</td>
<td>95.6</td>
<td>1.70</td>
<td>33.1</td>
<td>5.8</td>
</tr>
<tr>
<td>2</td>
<td>F</td>
<td>42</td>
<td>122.3</td>
<td>1.82</td>
<td>36.9</td>
<td>6.0</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>28</td>
<td>117.6</td>
<td>1.70</td>
<td>40.9</td>
<td>6.1</td>
</tr>
<tr>
<td>4</td>
<td>F</td>
<td>49</td>
<td>104.6</td>
<td>1.64</td>
<td>38.9</td>
<td>6.0</td>
</tr>
<tr>
<td>5</td>
<td>F</td>
<td>43</td>
<td>89.1</td>
<td>1.61</td>
<td>34.4</td>
<td>5.8</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>31</td>
<td>91.4</td>
<td>1.67</td>
<td>32.5</td>
<td>5.7</td>
</tr>
<tr>
<td>7</td>
<td>F</td>
<td>24</td>
<td>111.7</td>
<td>1.71</td>
<td>38.2</td>
<td>5.9</td>
</tr>
<tr>
<td>8</td>
<td>F</td>
<td>51</td>
<td>127.3</td>
<td>1.76</td>
<td>41.1</td>
<td>6.2</td>
</tr>
<tr>
<td>9</td>
<td>M</td>
<td>36</td>
<td>108.8</td>
<td>1.62</td>
<td>41.5</td>
<td>6.4</td>
</tr>
<tr>
<td>10</td>
<td>F</td>
<td>38</td>
<td>105.5</td>
<td>1.71</td>
<td>36.1</td>
<td>6.1</td>
</tr>
</tbody>
</table>

Mean ± SD: 37.5 ± 37.4 kg, 1.69 ± 0.1 m, 34.1 ± 0.6 kg/m², 6 ± 0.2

BMI = body mass index; F = female; HbA1c = hemoglobin A1c; M = male; SD = standard deviation.

Ethical Considerations
This pilot study was approved by the institutional review board. The risk and potential benefits of the procedures were explained to all patients, and written informed consent was obtained. The study was performed in accordance with the ethical principles of the Declaration of Helsinki.

Study Population
Between January 2017 and June 2018, 22 consecutive obese patients with prediabetes who were admitted to the Interventional Radiology Unit, Zagazig University Hospitals for LGAE for weight reduction were screened. The inclusion criteria for this study were (a) patients who had already failed with conservative methods (weight loss/exercise programs and medications) and were not interested in pursuing bariatric surgery, (b) body mass index (BMI) >30 kg/m², (c) HbA1c ranging from 5.7 to 6.4, (d) age 18–60 years, and (e) adequate hematological, hepatic, and renal function. The exclusion criteria were (a) patients with any known chronic disease or significant comorbidities (2 patients), (b) patients with a known history of bariatric surgery or any other gastric surgery (2 patients), (c) patients with a history of peptic ulcer or reflux (5 patients), (d) patients with diabetes or a family history of diabetes (2 patients), and (e) pregnancy (1 patient).

This process yielded a final cohort of 10 patients (7 women and 3 men; mean age 37.5 ± 8.8 years; range 24–51 years), all of whom were white, with a mean body weight of 107.4 ± 12.8 kg (range 89.1–127.3 kg), a mean BMI of 37.4 ± 3.3 kg/m² (range 32.5–41.5 kg/m²), and a mean HbA1c of 6 ± 0.2 (range 5.7–6.4). The baseline demographics and clinical characteristics of all patients are summarized in Table 1. The flow chart of our study is illustrated in Fig 1.

Patient Assessment
On admission, all patients underwent a detailed history, and a physical examination was performed by a clinician...
specializing in the evaluation and management of obese patients (M.A.). All patients were evaluated by an endocrinologist before participation in the study (A.A.F., with 17 years of experience in diabetes). The patients were not supplied with any specific instructions for improving their dietary or exercise habits and did not take any medication for diabetic control. An upper endoscopy examination was performed at baseline for all patients by an expert consultant who has 14 years of endoscopy experience and performs more than 250 endoscopy procedures per year. Patients with any abnormal endoscopic findings were excluded from the study. Follow-up endoscopy was performed in all patients at 1 week postprocedure. All laboratory and biochemical investigations, including HbA1c, were measured. Weight, height, BMI, and HbA1c were measured for each patient before the intervention and 6 months after; the differences were then calculated. A standardized single digital scale was used to weigh all patients throughout the study. The percent reduction was calculated using the formula 
(preprocedure – postprocedure)/preprocedure × 100. Once enrolled, all patients underwent LGAE for weight reduction. One investigator (M.A.A.B.) was responsible for collecting relevant data from each patient, following the patients through the course of study, and processing the data for analysis. A strict protocol of prophylactic therapy was followed, with oral omeprazole (40 mg twice daily) and sucralfate (1 g 4 times daily) 2 weeks before the intervention and continuing for 6 weeks after. Adverse events (AEs) were followed at each visit. AEs were classified as mild, moderate, or severe according to the new classification of the Society of Interventional Radiology (24).

**LGAE**

The procedure was performed using an angiography unit (Artis zee Ceiling VC21C Cath Lab System, Siemens, Erlangen, Germany). All procedures were performed by 3 interventional radiologists (S.B.E., F.H., and M.M.A.Z.,

---

Figure 1. CONSORT flow chart.

Excluded (n=12)
1. Known chronic disease or significant comorbidities (n=2).
2. History of bariatric surgery or any other gastric surgery (n=2).
3. History of peptic ulcer or reflux (n=5).
4. Diabetic patients (n=2).
5. Pregnant women (n=1).

Analysed (n= 10) Excluded from analysis (n = 0)
with 15, 13, and 10 years of experience, respectively) using the same technique. Under local anesthesia, the patient’s femoral artery was punctured, and a 5 F introducer sheath was placed. Digital subtraction angiography (DSA) of the celiac artery was performed using a 4- or 5-F cobra catheter (Imager-Boston Scientific, Natick, Massachusetts) to identify the origin of the left gastric artery (LGA) and any anatomic variants (Fig 2). After identification of the LGA, selective catheterization of the LGA was performed using a microcatheter (Renegade HI-FLO microcatheter, Boston Scientific). Diagnostic DSA of the LGA was performed to exclude fundal perfusion defects that may indicate collateral supply and warrant embolization of other arteries. Embosphere microsphere particles (Merit Medical Inc., Jordan, Utah), 300–500 μm in diameter immersed in 10 mL contrast medium (Omnipaque 350; GE Healthcare, Little Chalfont, United Kingdom), were used for embolization in all patients. The embolization was performed by slow pulsatile injections of the particles using a Luer-Lock 3 mL syringe. The embolization procedure was considered satisfactory when a stasis of flow in the main stem of LGA was observed for at least 5 cardiac beats and reflux appeared around the microcatheter tip upon a slight push using the 3-mL syringe. Saline was then injected slowly until clearance of the particles from the microcatheter. Next, the gastric fundal blush was evaluated again by selective DSA; if a blush was present, embolization was continued until absence of the blush and occurrence of complete stasis of flow in the main LGA (Fig 2). Delayed DSA was performed after 5 minutes to exclude any recanalization of the embolized artery and to identify any nontargeted embolization. Finally, the guide wire and microcatheter were withdrawn, the patients were transferred to a monitored unit where the introducer sheath was removed, and manual pressure was applied to obtain hemostasis.

Figure 2. Example of bariatric embolization in a 49-year-old white woman with a baseline weight of 104.6 kg, a baseline BMI of 38.9 kg/m², and a baseline HbA1c of 6. She demonstrated a weight of 98.2 kg, a BMI of 36.5 kg/m², and an HbA1c of 5.1 at 6 months after LGAE. These results represent percent reductions of 6.1% in weight, 6.2% in BMI, and 17.7% in HbA1c. (a) Celiac angiogram obtained before LGAE shows the classic LGA anatomy, with the LGA arising from the proximal celiac artery (1 = celiac artery, 2 = LGA, 3 = common hepatic artery, 4 = splenic artery, 5 = inferior phrenic artery, 6 = gastroduodenal artery). (b) Selective angiogram of the posterior branch of the LGA obtained before bariatric embolization shows gastric fundal blush (arrow). (c) Selective angiogram of the anterior branch of the LGA obtained before bariatric embolization shows gastric fundal blush (arrow). (d) LGA angiogram obtained after bariatric embolization shows the absence of gastric fundal blush (arrows).
Table 2. Changes in Body Weight, BMI, and HbA1c 6 Months after Embolization

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Weight, kg</th>
<th>BMI, kg/m²</th>
<th>HbA1c</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>86.4</td>
<td>29.9</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>110.2</td>
<td>33.3</td>
<td>4.5</td>
</tr>
<tr>
<td>3</td>
<td>107.5</td>
<td>37.2</td>
<td>5.5</td>
</tr>
<tr>
<td>4</td>
<td>98.2</td>
<td>36.5</td>
<td>5.1</td>
</tr>
<tr>
<td>5</td>
<td>81.5</td>
<td>31.4</td>
<td>4.8</td>
</tr>
<tr>
<td>6</td>
<td>83.1</td>
<td>29.8</td>
<td>3.7</td>
</tr>
<tr>
<td>7</td>
<td>101.8</td>
<td>34.8</td>
<td>4.9</td>
</tr>
<tr>
<td>8</td>
<td>115.9</td>
<td>37.4</td>
<td>5.3</td>
</tr>
<tr>
<td>9</td>
<td>98.3</td>
<td>37.5</td>
<td>5.5</td>
</tr>
<tr>
<td>10</td>
<td>96.6</td>
<td>33</td>
<td>4.1</td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>98 ± 11.6</td>
<td>34.1 ± 3</td>
<td>4.7 ± 0.6</td>
</tr>
<tr>
<td>P</td>
<td>&lt;.0001</td>
<td>&lt;.0001</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>

BMI = body mass index; HbA1c = hemoglobin A1c; SD = standard deviation.

Outcome Measures and Statistical Analysis

The primary end point was a reduction in HbA1c. The secondary end points included reductions in weight and BMI and the safety of LGAE. The collected data were computerized and statistically analyzed using MedCalc (version 11.1; MedCalc, Mariakerke, Belgium). Quantitative data were expressed as the mean ± standard deviation. Pre- and post-procedure body weight and HbA1c were compared using a paired sample t test. The correlation between BMI and HbA1c was calculated using Pearson’s correlation coefficient, and the results are reported as an r value with a P value. A P value of .05 was considered to indicate statistical significance.

RESULTS

Ten patients who suffered from prediabetes and obesity and underwent LGAE for weight loss were enrolled in this study. The technical success of this study was 100%. No fundal perfusion defects were detected in our patients, and the fundus was exclusively supplied by the LGA. The average duration of the procedure (from groin puncture to sheath removal) was 25.3 ± 6.3 minutes (range 15–35) with an average fluoroscopy time of 15.5 ± 4.4 minutes (range 9–22 minutes).

All procedures were successfully completed without any moderate or severe AEs. According to the new classification of Society of Interventional Radiology guidelines, there were 7 mild AEs not requiring hospitalization and needing only nominal therapy. Only mild epigastric pain occurred in 7 patients (70%) and disappeared within 24 hours. Neither nausea nor vomiting occurred. All patients were discharged from the hospital within an average duration of 21.8 ± 7.6 hours after the procedure (range 12–36). Endoscopy performed in all patients at 1 week postprocedure revealed no significant abnormalities.

Six months after the procedure, the mean body weight and BMI had significantly decreased to 98 ± 11.6 kg and 34.1 ± 3 kg/m², respectively (P < .0001). The paired sample t test showed a statistically significant reduction in HbA1c from pre- to postprocedure (6.1 ± 0.2 preprocedure vs 4.7 ± 0.6 postprocedure, P < .0001) (Table 2).

All patients showed a reduction in body weight, BMI, and HbA1c; the mean percent reductions were 8.9% ± 1.2 (range 6.1%–10.6%), 8.8% ± 1 (range 6.2%–9.8%), and 21.4% ± 8.9 (range 9.8%–35%), respectively (Table 3).

A statistically significant positive correlation was found between BMI and HbA1c after the procedure (r = 0.91, confidence interval = 0.66 to 0.98, P = .0002) (Fig 3).

DISCUSSION

Preliminary data from this pilot study demonstrated a statistically significant weight loss (P < .0001) within a short period (6 months after the procedure) with a mean percent reduction in body weight and BMI of 8.9% and 8.8%, respectively. A concomitant statistically significant decrease in HbA1c to normal levels was also detected (P < .0001), and all patients in this study resolved their prediabetic state in this short period with a mean percent reduction in HbA1c of 21.4%. Our study confirmed that the weight loss resulting from LGAE appeared to have had a considerable effect on the HbA1c parameter within a short period. Our findings are congruent with those published by previous trials (19–23), which demonstrated positive preliminary results for weight loss in the short to medium term (an 8%–10% total weight loss over a 6- to 12-month period, on average). Three studies (20,22,23) included diabetic and obese patients, whereas 1 study (21) excluded them. Syed et al. (20) reported 1 diabetic patient who had significant weight loss and a reduction in HbA1c level (from 7.4% to 6.3%) at 3 and 6 months postprocedure. However, because this report was only a single-patient experience, Syed et al. did not report definitive conclusions about the efficacy of bariatric embolization in diabetic patients.

Based on our findings, which confirm those of previously published studies (19–23), and in view of the significant effects of LGAE on body weight and HbA1c, our data...
highlight the promising ability of LGAE to reduce weight and improve HbA1c in obese, prediabetic patients and confirm that obese, prediabetic patients are a subgroup that might benefit from this procedure. Furthermore, LGAE might be performed not only for morbidly obese patients, but also for patients who require support for improving other chronic diseases such as diabetes and hypertension and should be studied further.

Regarding the safety of the procedure, in line with the preliminary results of previous trials (19–23), our study revealed no severe AEs within the follow-up period of 6 months. Although a major concern regarding gastric embolization is the risk of gastric mucosal ulceration, endoscopy performed in all patients at 1 week postprocedure revealed no significant abnormalities.

To date, only patients with a BMI >40 kg/m² have been allowed to participate in clinical trials per the US Food and Drug Administration and European trials (25). Interestingly, the patients reported in our study are different from those in previously published series. Our study included patients with lower baseline BMI (37.4 ± 3.3 kg/m²) and few patients having BMIs over 40 kg/m², unlike previous trials, which reported BMI values ranging from 42 to 52 kg/m² (19–21,23). However, Bai et al. (22) included 3 patients with a BMI <40 kg/m² and recommended more diverse enrollment in future studies to provide deep insight into LGAE. In agreement with Bai et al. (22), our study supports that a large population of patients with BMI <40 kg/m² may potentially benefit from this procedure.

The current study was able to link the reduction in HbA1c to the reduction in BMI after LGAE. A statistically significant positive correlation was found between BMI and HbA1c (r = 0.91, P = .0002); therefore, the reduction in HbA1c levels in our study can be explained by the greater reduction in BMI. The link between glycemic control and BMI reduction has been reported in previous bariatric surgery studies (26–29).

This study expands the literature by providing preliminary insight into the promising potential of LGAE to improve BMI and HbA1c in obese, prediabetic patients. Moreover, it establishes the basis for future studies to evaluate the efficacy of LGAE in chronic disease associated with obesity. Nevertheless, the current study had some limitations. First, the small size of the study population. Second, the duration of the study is too short to allow conclusions regarding HbA1c reduction durability. Third, data were collected preprocedure and at 6 months postprocedure only rather than by using multiple records (e.g., baseline, 3, 6, and 12 months). Finally, the lack of a control group does not allow definitive conclusions regarding the net effect of LGAE on prediabetes. Even though we attempted to provide matched controls, controlling for the many other potentially confounding variables involved in weight loss during this short period was very difficult.

Despite these limitations, the study findings represent preliminary highlights of the clinical outcomes of LGAE on achieving optimal glycemic control in prediabetes.

In conclusion, in obese patients who are prediabetic, LGAE is well tolerated and is associated with significant weight loss and a concomitant decrease in HbA1c at the 6-month follow-up. Larger longitudinal studies are still needed to demonstrate the long-term benefits for these patients and
those who have type 2 diabetes, and to elucidate possible mechanisms of action.

ACKNOWLEDGMENTS

The authors thank all staff members and colleagues in the Radiology Department-Zagazig University-Egypt for their helpful cooperation and all the study participants for their patience and support.

REFERENCES