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# The impact of bariatric surgery on in-patient clinical outcomes among patients with autoimmune hepatitis

Catherine Choi, MD[a,*], Aldo Barajas-Ochoa, MD[a], Aditya Uppuluri, MD[a], Grace Ro, BS[b], Reza Hashemipour, MD[c], Yi Jiang, MD[a], Umair Nasir, DO[a], Sushil Ahlawat, MD[c]

**Abstract**

Autoimmune hepatitis (AIH) is a form of liver inflammation in which immune cells target hepatocytes, inducing chronic inflammatory states. Bariatric surgery (BS) was shown to reduce inflammation in severely obese patients. We hypothesize that obese patients with AIH and BS have lower prevalence of liver-related complications and in-patient mortality compared to those without BS.

The National Inpatient Sample from 2007 to 2013 was queried for hospitalizations of adults over 18 years of age with a diagnosis of AIH. Of those, hospitalizations with BS were selected as cases and those with morbid obesity as controls. Case-control 1:2 matching was done based on sex, age, race, and comorbidities. Primary outcomes were prevalence of liver-related complications and in-patient mortality. Independent risk factors of in-patient clinical outcomes were identified using multivariate regression analysis.

From 137,834 hospitalizations with a diagnosis of AIH, 688 with BS were selected as cases, and 1295 were matched as controls. The prevalence of ascites was higher in the BS group compared to the control (odds ratio 1.73, 95% confidence interval (CI) 1.27–2.36). The prevalence of cirrhosis (36.8% vs 33.2%), portal hypertension (7.4% vs 10.0%), hepatic encephalopathy (10.6% vs 8.7%), and varices and variceal bleeding (3.9% vs 5.5%) was not statistically different from case controls, ($P > .05$).

BS was an independent risk factor for ascites (adjusted odds ratio (aOR) 1.87; 95% CI 1.36–2.56) and hepatic encephalopathy (aOR 1.42; 95% CI 1.03–1.97) but was an independent protective factor against in-patient mortality (aOR 0.21, 95% CI 0.08–0.55) once adjusted for age, sex, race, and comorbidities.

**Abbreviations:** AIH = autoimmune hepatitis, aOR = adjusted odds ratio, BS = bariatric surgery, CI = confidence interval, ECI = Elixhauser comorbidity index, ICD = international classification of diseases, LOS = length of hospital stay, NAFLD = non-alcoholic fatty liver disease, NASH = non-alcoholic steatohepatitis.

**Keywords:** autoimmune, bariatric surgery, hepatitis, inflammation, obesity

## 1. Introduction

Autoimmune hepatitis (AIH) is a chronic progressive inflammatory liver disease whose exact pathophysiology remains unknown.[1,2] The proposed mechanism behind autoimmune liver damage involves the interplay between genetic predisposition, environmental triggers, and an impaired immunoregulatory system.[1,2] The hallmark histological feature of AIH is interface hepatitis: lymphoplasmacytic infiltrates invade the liver parenchyma, and lymphocytes, plasma cells, and histiocytes surround the dying hepatocyte at the portal-parenchymal interface and in the lobule.[1,2] Common triggers of AIH include infections, medications, and toxins.[2] Regardless of the triggers, immune dysregulation is thought to be the main driving pathogenesis behind autoimmune liver damage.

Obesity leads to a low-grade systemic inflammatory state with impaired immune cell functions, altered lymphocyte numbers, and dysregulated cytokine profiles.[3] In previous studies, such as a study by Kral et al[4], weight loss induced by bariatric surgery (BS) in severely obese patients reduced the inflammatory state, and liver fibrosis. In addition to its contribution to systemic inflammatory states, obesity has also been shown to affect T cell function and increase the severity of AIH without significantly reducing the acute T cell response.[3]

The role of weight loss in the management of obesity-related chronic liver diseases such as non-alcoholic fatty liver disease (NAFLD) and non-alcoholic steatohepatitis (NASH) has been shown to not only reduce fibrosis but also obesity-related metabolic abnormalities. However, it remains elusive whether the inflammatory state and its effects on immunologic derangements caused by obesity can lead to worse outcomes in AIH. There are limited studies exploring the link between obesity and AIH. We hypothesized that weight loss induced by BS wound have clinical benefits for patients with AIH and therefore expected lower

*Editor: Muhammed Mubarak.*

*The authors have no funding and conflicts of interest to disclose.*

*The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.*

*[a] Internal Medicine, Rutgers New Jersey Medical School, [b] Rutgers New Jersey Medical School, [c] Department of Gastroenterology and Hepatology, Rutgers New Jersey Medical School, Newark, NJ, USA.*

*[*] Correspondence: Catherine Choi, Internal Medicine, Rutgers New Jersey Medical School, 150 Bergen Street, UH I-248, Newark 07103, NJ, USA (e-mail: Cjc413@njms.rutgers.edu).*



*How to cite this article: Choi C, Barajas-Ochoa A, Uppuluri A, Ro G, Hashemipour R, Jiang Y, Nasir U, Ahlawat S. The impact of bariatric surgery on in-patient clinical outcomes among patients with autoimmune hepatitis. Medicine 2020;99:42(e22446).*

*Received: 7 May 2020 / Received in final form: 23 July 2020 / Accepted: 15 August 2020*

*http://dx.doi.org/10.1097/MD.0000000000022446*

prevalence of liver-related complications, in-patient mortality, and hospital costs. We aimed to determine rates of in-patient mortality and of liver-related complications including cirrhosis, portal hypertension, hepatic encephalopathy, ascites, hepatorenal syndrome, varices and variceal bleeding, and spontaneous bacterial peritonitis in AIH patients with or without BS based on nationally representative data. We also sought to determine resource utilization by measuring length of hospital stays (LOS) and total hospital charges in AIH patients with or without BS.

## 2. Materials and methods

### 2.1. Data source and study population

This study is a retrospective analysis of the 2007 to 2013 Healthcare Cost and Utilization Project-National Inpatient sample (HCUP-NIS). The NIS is the largest all-payer inpatient database in the United States, and is part of the Healthcare Cost and Utilization Project, sponsored by the Agency for Healthcare Research and Quality.[5] This database includes clinical and resource use information extracted from billing data for hospital stays.

Results were extracted from the NIS database by identifying hospitalizations of patients above the age of 18 years with a diagnosis of AIH and its corresponding International Classification of Diseases (ICD)-9 procedure code (571.42). Of these, hospitalizations of patients with either prior BS or morbid obesity were extracted (N = 137,834).

AIH hospitalizations with BS were assigned to the cases group. The control group was selected by performing a case-control matching at a ratio of 1 case to 2 controls, based on sex, age, race, and comorbidities. Sex was a dichotomic variable (female, male). The age in years was transformed into a categorical variable with 8 different groups: 18 to 27, 28 to 37, 38 to 47, 48 to 57, 58 to 67, 68 to 77, 78 to 87, and 88 or older. The Elixhauser comorbidity index (ECI) is a score of weighted sums of comorbid conditions, and it was developed to assess influence of comorbidities on the outcomes of patients.[6,7] In the ECI scoring system, a total 29 comorbid conditions were used to develop a weight for each patient. In our study, ECI was converted to 5 groups: ECI up to –1, ECI of 0, ECI of 1 to 5, ECI of 6 to 10, and ECI of 11 or higher. The model design is shown in Figure 1.

For each hospitalization, the variables age, race, sex, ECI, insurance type, length of hospital stay, total hospital charges, in-patient mortality, and various liver-related AIH complications were obtained. The liver-related complications studied were cirrhosis, portal hypertension, hepatic encephalopathy, ascites, hepatorenal syndrome, varices and variceal bleeding, and spontaneous bacterial peritonitis. The primary outcomes of this study were the rate of liver-related complications and in-patient mortality in the case and control group. The secondary outcomes were resource utilization based on LOS and total hospital charges for the case and the control groups.

Univariate logistic regression analyses were performed to obtain odds ratios of the complications, and multivariate logistic regression analyses were used to adjust for age, race, sex, and ECI.

The analysis was performed with de-identified data and was therefore exempt from IRB approval.

### 2.2. Statistical analyses

All data analyses were conducted using SPSS, version 26.0 (IBM Corp, Armonk, NY). Individual discharge-level weights were

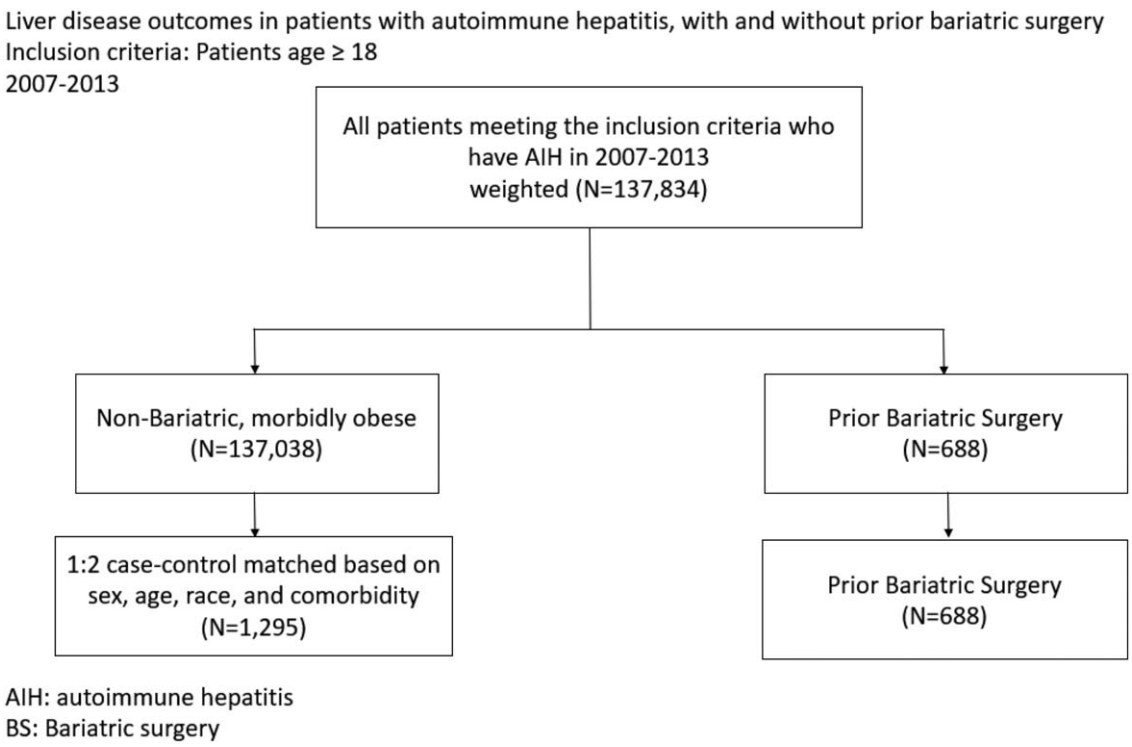


**Figure 1.** Diagram of study design. Diagram of study population showing selection process for the case and control groups. For each patient with prior bariatric surgery, 2 patients with morbid obesity were selected with matching sex, age, race, and comorbidities.

**Table 1**

**Patient characteristics and hospital characteristics.**

| | Prior bariatric surgery N = 688 | Morbid obesity N = 1295 | *P* value |
|---|---|---|---|
| Patient Age, yr (%) | | | .95 |
| 18–27 | 20 (2.9%) | 39 (3.0%) | |
| 28–37 | 87 (12.6%) | 145 (11.2%) | |
| 38–47 | 189 (27.5%) | 347 (26.8%) | |
| 48–57 | 198 (28.8%) | 370 (28.6%) | |
| 58–67 | 164 (23.8%) | 333 (25.7%) | |
| 68–77 | 25 (3.6%) | 50 (3.9%) | |
| 78–87 | 5 (0.7%) | 11 (0.8%) | |
| 88 and older | 0 (0%) | 0 (0%) | |
| Sex | | | .41 |
| Female, N(%) | 644 (93.6%) | 1,224 (94.5%) | |
| Male, N(%) | 44 (6.4%) | 71 (5.5%) | |
| Race | | | .64 |
| White, N(%) | 494 (71.8%) | 950 (73.4%) | |
| Black, N(%) | 108 (15.7%) | 201 (15.5%) | |
| Others, N(%) | 86 (12.5%) | 144 (11.1%) | |
| Elixhauser comorbidity index, N(%) | | | .42 |
| ≤ -1 | 185 (26.9%) | 369 (28.5%) | |
| 0 | 15 (2.2%) | 15 (1.2%) | |
| 1–5 | 173 (25.1%) | 312 (24.1%) | |
| 6–10 | 139 (20.2%) | 272 (21.0%) | |
| ≥11 | 176 (25.6%) | 327 (25.3%) | |
| Primary payer, N(%) | | | <.05 |
| Medicare | 474 (36.6%) | 254 (36.9%) | |
| Medicaid | 224 (17.3%) | 59 (8.6%) | |
| Private | 534 (41.2%) | 356 (51.7%) | |
| Self-Pay | 49 (3.8%) | 15 (2.2%) | |
| Others | 14 (1.1%) | 5 (0.7%) | |
| LOS, d (SD) | 4.1 (2.7) | 6.0 (7.3) | <.05 |
| In-patient mortality, N(%) | 5 (0.7%) | 40 (3.1%) | <.05 |
| Total hospital charges, $ | $ 32,562 (32,375) | $ 44,551 (54,849) | <.05 |

used to obtain estimates at the national level of patients admitted with a diagnosis of AIH in the U.S.A. Proportions were compared with Chi-squared tests while continuous variables were analyzed with independent *t* tests. All statistical analyses were 2-sided, and results with a cutoff *P*-value less than .05 considered statistically significant. Univariate logistic regression analyses were performed to assess the odds of complications and in-patient mortality in hospitalized patients with AIH with or without BS. Multivariate logistic regression analyses were used to adjust for age, sex, race, and ECI.

## 3. Results

### 3.1. Patient characteristics and insurance types

In the NIS database from 2007 to 2013, there were 137,834 hospitalized cases with a diagnosis of AIH in the United States. Of these, 688 (644 women) were selected as cases, and 1295 (1244 women) were matched as controls. Table 1 shows the demographic characteristics after matching. Most patients with BS were in the age groups 48 to 57 (28.8%), 38 to 47 (27.5%), and 58 to 67 (23.8%). Most patients in the case group were White (71.8%), with only 15.7% Black (15.7%). Many patients with BS had an ECI greater than 11 (25.6%), followed by between 1 and 5 (25.1%). 41.2% of the patients in the case group and 51.7% in the control group were insured by private insurance.

### 3.2. Length of stay in hospital and total hospital charges

Hospitalizations of patients with prior BS were shorter and less expensive when compared to the controls. The mean LOS was 4.1 days (±2.7) in the case group, and 6.0 days (±3 days) for the control group whereas the hospital charges were $32,562 (±2375) for the case group and $44,551 (±3849) for the control group.

### 3.3. Primary outcomes

Table 2 shows the prevalence of in-patient mortality and liver-related complications for both groups. There were 5 (0.7%) in-patient deaths in the cases group, and 40 (3.1%) in the control group, $P < .05$. The small number of in-patient mortalities precluded further analyses of this variable. Regarding the prevalence of liver-related complications, the prevalence of ascites was higher in the cases group than in the control group (odds ratio 1.73, 95% confidence interval (CI) 1.27–2.36). The frequency counts of hepatorenal syndrome and SBP were too small, and therefore univariate regression analysis was not performed. There were no differences between case and controls in the prevalence of cirrhosis (36.8% vs 33.2%, $P = .11$), portal hypertension (7.4% vs 10.0%, $P = .06$), hepatic encephalopathy (10.6% vs 8.7%, $P = .18$), or varices and variceal bleeding (3.9% vs 5.5%, $P = .14$).

### 3.4. Independent predictors of in-patient mortality and liver-related complications

Patient age, sex, race, and comorbidity (ECI) were included in the final multivariate regression analysis in order to determine

**Table 2**

**Univariate analysis of in-patient mortality and liver-related complications.**

| | Prior bariatric surgery N = 688 | Morbid obesity N = 1295 | OR, 95% CI | *P* value |
|---|---|---|---|---|
| Cirrhosis | 253 (36.8%) | 430 (33.2%) | 1.17 (0.96-1.42) | .11 |
| Portal Hypertension | 51 (7.4%) | 129 (10.0%) | 0.72 (0.52–1.01) | .06 |
| Hepatic encephalopathy | 73 (10.6%) | 113 (8.7%) | 1.24 (0.91–1.69) | .18 |
| Ascites | 84 (12.2%) | 96 (7.4%) | 1.73 (1.27–2.36) | <.05 |
| Hepatorenal syndrome | 0.00% | 16 (1.2%) | * | |
| Varices and variceal bleeding | 27 (3.9%) | 71 (5.5%) | 0.71 (0.45–1.12) | .14 |
| Spontaneous bacterial Peritonitis | 5 (0.7%) | 5 (0.4%) | * | |
| In-patient mortality | 5 (0.7%) | 40 (3.1%) | * | |

* Sample size precluded further analysis.

CI = confidence interval, OR = odds ratio.

**Table 3**

**Multivariate regression analysis of in-patient mortality and liver-related complications.**

| Outcomes | BS, aOR | 95% CI |
|---|---|---|
| Cirrhosis | 1.17 | 0.95–1.43 |
| Portal hypertension | 0.71 | 0.50–1.02 |
| Hepatic encephalopathy | 1.42 | 1.03–1.97 |
| Ascites | 1.87 | 1.36–2.56 |
| Hepatorenal syndrome | * | |
| Varices and variceal bleeding | 0.72 | 0.45–1.15 |
| Spontaneous bacterial Peritonitis | * | |
| In-patient mortality | 0.21 | 0.08–0.55 |

aOR = adjusted for age, BS = bariatric surgery, CI = confidence interval, sex = race, comorbidity.

whether BS was an independent predictor for the in-patient mortality and liver-related complications. BS was an independent risk factor for hepatic encephalopathy (adjusted odds ratio (aOR) 1.42; 95% CI 1.03–1.97) and ascites (aOR 1.87; 95% CI 1.36–2.56) when adjusted for age, sex, race, and ECI. The multivariate regression analysis of in-patient mortality and liver-related complications is further delineated in Table 3. BS was a protective factor against in-patient mortality (aOR 0.21; 95% CI 0.08–0.55). BS was not independently associated with cirrhosis, portal hypertension, and varices and variceal bleeding. Hepatorenal syndrome and SBP had small frequency counts, and therefore multivariate analysis was not performed.

## 4. Discussion

There has been an established association between metabolic syndrome, inflammation and fibrosis in severely obese people, implying pathogenetic effects of obesity in hepatic fibrogenesis.[4] In a study by Kral et al where they studied 104 patients with severe obesity before and after substantial sustained weight loss, repeat liver biopsies demonstrated improvements of steatosis, and even reversal of fibrosis in some cases.[4] The benefits of weight loss were also demonstrated in those with obesity by reducing obesity-related morbidity and mortality.[8] There were improvements in all features of metabolic syndrome in patients after BS, and the proposed mechanisms include improvement of insulin resistance, dyslipidemia, inflammation, increasing adiponectin, weight loss, and decreasing intestinal hormones.[8] While there is an established association between obesity and NAFLD, there are limited studies on the link between AIH and obesity. Regardless of the antigenic triggers, the response of hepatocytes to chronic inflammation in AIH plays an essential role in the physiopathology of liver fibrosis.[9] As obesity and AIH both manifest as inflammatory changes of the liver, we aim to investigate the potential link between these processes.

This is the first national database study to explore the effects of the presumed weight loss induced by BS on

1) in-patient mortality,
2) liver-related complications and
3) resource utilizations.

Hospitalized AIH patients with BS had shorter length of stay and lower hospital charges compared to those without prior BS. Case-control matching accounted for patient-related confounding factors including age, sex, race, and comorbidity. BS was an independent risk factor for ascites and hepatic encephalopathy, but it was a protective factor against in-patient mortality.

The main mechanism of liver damage in AIH is an aggressive cellular immune attack, which is demonstrated by immunohistological findings where CD4 T cells predominate with a sizeable number of CD4 T cells.[1] The liver damage in AIH is a complex process involving both the innate and adaptive immune system. In obesity, adipocytes secrete pro-inflammatory cytokines and chemokines, which can attract and activate macrophages and other immune cells.[10,11] Multiple pro-inflammatory cytokines have been shown to play an essential role in obesity-induced inflammation such as interleukin-1β and tumor necrosis factor-α leading to immunological imbalance.[10] However, the extent to which obesity modulates immune responses in AIH is not clear. A study by Gaur et al using a mouse model to investigate the impact of obesity on T cells in the liver demonstrated a reduction in antigen clearance capacity in obese mice in the setting of autoimmunity.[3] It also showed that obesity affects T cell function and increases the severity of AIH.[3] With the above-mentioned link between obesity and inflammation in the setting of inflammatory liver damage in AIH, we hypothesized that the liver-related complications would be mitigated upon significant weight loss by BS in a reduced inflammatory state. Although there was reduced in-patient mortality associated with BS, potentially due to improvement of fibrosis by BS-induced weight loss, the prevalence of ascites and hepatic encephalopathy was higher in the BS group compared to the control group. This is contrary to our expectation that clinical benefits are associated with less reduced systemic inflammation induced by improving obesity. Possible explanations for worsened ascites and hepatic encephalopathy in the BS group include

1) liver dysfunction related to the BS procedure itself, rapid weight loss, or other undefined factors associated with malabsorption[12] and
2) worsening metabolic derangements from corticosteroid treatment as part of AIH management.

Eilenberg et al[12] reported a case series of 10 patients who had liver dysfunction with a mean postoperative follow-up of 15 months after Roux-en Y gastric bypass and 1-anastomosis gastric bypass (OAGB). The underlying mechanism of liver dysfunction after BS could be related to pre-existing cirrhosis, as up to 5% of morbidly obese patients can have undiagnosed cirrhosis.[12] 60% of the patients in the study by Eilenberg et al[12] had underlying liver diseases, and those with preoperative diagnosis of NAFLD had significantly aggravated NAFLD after BS. In patients with pre-existing NASH, the severity of liver disease was associated with higher mortality during long-term follow-up.[12] Therefore, it was thought that these patients with existing liver disease were more susceptible to liver injury from rapid weight loss or other undefined factors by malabsorptive processes induced by BS. One caveat to this study was a relatively short follow-up period (mean of 15 months). If these are transient liver dysfunctions related to the risks involved with the procedure itself, studies with longer follow-up and larger sample sizes are warranted to accurately measure the prevalence and degree of liver deterioration after BS. In our study, due to the nature of NIS database, no long-term follow-up data was available; therefore, our findings were limited to short-term outcomes as it was based on in-patient data. A careful pre-operative screening and possibly excluding those with advanced liver disease will be important

when considering BS as a treatment option for obesity due to potential post-operative risks of worsening liver function.

Another explanation for more frequent ascites and hepatic encephalopathy in the BS group may be related to the management of AIH, which may worsen steatosis and fibrosis of the liver. In typical cases of AIH, hepatic fibrosis may be reversible in patients who are responsive to medical steroid treatment. For instance, in a case-series by Dufour et al, 8 patients with AIH had marked reduction or regression of hepatic fibrosis in response to medical treatment as was shown by subsequent biopsy.[13] However, in patients with AIH and co-existing steatosis or NASH, clinical outcomes may vary with standard AIH treatment. De Luca-Johnson et al performed a retrospective study of 73 patients to determine the clinical outcomes of patients with coincident AIH and NAFLD.[14] This study showed that patients with AIH and NASH were more likely to present with cirrhosis and have more adverse clinical outcomes compared to AIH-only patients.[14] This study highlights the diagnostic and therapeutic challenges of co-existing AIH and NAFLD as the management of each condition is very different.[14] Although non-glucocorticoid therapy is available, the standard therapy for AIH is glucocorticoids, which can exacerbate underlying NAFLD. There is a lack of treatment that can improve both conditions. Perhaps co-existing steatosis and its related liver changes may explain more frequent ascites and hepatic encephalopathy in our study population. However, our sub-analysis study showed no difference in prevalence of NAFLD against case controls (34.5% vs 36.7%, $P = .66$). Unfortunately, there is no available data of the severity of NAFLD in the NIS database. As the prevalence of NAFLD was not different between the 2 groups, a possible explanation may be related to uncaptured differences in the severity of pre-existing liver diseases. The impact of pre-existing NAFLD on liver-related complications remains unclear.

In our study, a reduced in-patient mortality rate was noted among patients with AIH who underwent BS compared to those who did not (0.7% vs 3.1%, $P < .05$), and BS was independently associated with reduced in-patient mortality rate when adjusted for age, sex, race, and comorbidity. Obesity is a well-known risk factor for progression of liver fibrosis chronic liver diseases and all-cause mortality,[15,16] and a large, retrospective study utilizing the NIS by Akinyemiju et al showed a bell-shaped relationship between BMI and in-patient mortality among patients with a primary diagnosis of cancer, COPD, asthma, and cardiovascular disease.[16] Yet, there have been mixed results of the association between elevated BMI and all-cause mortality in prior studies; Janssen and Mark[17] performed a meta-analysis examining the association between the BMI and all-cause mortality in the elderly, which showed moderate obesity was associated with a modest increase in risk for mortality while overweight was not associated with a significantly increased risk of mortality. Another meta-analysis by Flegal et al[18] showed overall obesity was associated with higher all-cause mortality in the elderly. We observed BS was an independent protective factor against in-patient mortality, and likely explanation is the resolution of obesity as obesity is a risk factor for progression of fibrosis in patients with chronic liver diseases. Unfortunately, specific fibrosis of specific stage of AIH is not included in the NIS, and therefore we were unable to examine the improvement of fibrosis by BS-induced weight loss. BS was independently associated with in-patient mortality but higher rates of ascites and hepatic encephalopathy among patients with AIH. As discussed above, possible explanations for such discrepancy are the impact of BS on liver function after BS and the benefits of BS-induced weight loss. Our study explored the short-term effects of BS on parameters of cirrhosis and overall mortality while patients are hospitalized, and therefore further studies are warranted to explore the degree of impact of BS on the fibrosis in patients with AIH and long-term effects on mortality and liver-related complications.

Among hospitalized patients with AIH, the patients with BS had shorter LOS (4.1 day vs 6.0 day, $P < .05$, with and without BS) and lower total hospitalization charges ($32,562 vs $44,551, $P < .05$, with and without BS) compared to those without BS. The shorter LOS and lower total hospitalization charges are as expected due to the benefit of BS-induced weight loss, given comorbidities, complications, and longer recovery associated with higher BMI.[16] However, prior studies have shown conflicting results; Akinyemju et al showed higher BMI had shorter hospital stays among patients admitted with a primary diagnosis of cancer, COPD, asthma, and cardiovascular disease, and Hauck and Holingsworth[19] showed surgically managed obese patients had decreased length of stay in hospital for 122 Australian public hospitals. Possible explanations for the mixed results between our study and prior studies, which showed shorter hospital stays among obese patients are

1) obese surgical patients may have shorter hospital stays as they are more likely to be discharged to skilled nursing facilities compared to hospice care or their homes, or
2) methodological biases as a result of differing BMI cut-offs.[13,16]

The AIH patients are known to develop other concurrent autoimmune diseases due to significant epidemiologic, genetic, and immunologic overlap between immune-mediated rheumatologic diseases, and autoimmune liver diseases.[20] Most rheumatologic diseases manifest with elevated liver enzymes, but without significant parenchymal diseases.[20] Autoimmune thyroid disease and Sjogren syndrome are the most common extrahepatic autoimmune diseases among patients with autoimmune liver diseases.[21] It is critical to differentiate between rheumatologic disease-induced hepatitis and AIH due to therapeutic and prognostic implications; for instance, systemic lupus erythematous (SLE)-induced hepatitis and AIH both manifest as polyarthralgia, elevated gamma globulins and a positive antinuclear antibody, but further laboratory evaluation with serum antibodies, complement levels and liver histology can help differentiate between the 2 conditions.[21] Therefore, it would be interesting to evaluate how BS can affect the disease course of extrahepatic autoimmune conditions among the patients with AIH who have concurrent autoimmune diseases. Furthermore, future studies with available immune phenotyping data can help provide insight into the mechanism for the BS-induced clinical benefits observed in our study by examining phenotypical, functional, and activating properties of immune cell populations involved in the pathogenesis of AIH.[22]

### 4.1. Limitations

Our analysis is mainly limited by the nature of NIS. The NIS relies on accurate billing by clinicians to capture the diseases and complications, which may lead to undercoding diagnoses. Additionally, it is challenging to monitor long term clinical outcomes such as liver-related complications which are not

recorded in the NIS. Another limitation is the inability to differentiate the severity or types of BS, so we were unable to account for different anatomic constraints and associated risks of the surgery itself. The temporal relationship between the onset of AIH liver-related complications and BS cannot be established, as well as their severity or progression, due to the cross-sectional nature of this database. Also, since there was no data on medications, we were unable to measure the effects of medications on our outcomes. The differences in medications may contribute to outcomes. For example, the patients who were on corticosteroid treatment may have had a different hospital course compared to those who were not.

Lastly, as there is no specific diagnosis code for non-alcoholic steatohepatitis in ICD-9, we were not able to identify a subset of patients with NASH among patients included in the study. This is because autoimmune markers associated with AIH are also often detected in patients with NASH. NIS database with ICD-9 was selected for the study for its large sample size as compared to those with ICD-10; NIS database with ICD-10 is only available in the last few years. Therefore, it would be interesting to conduct a study where we can account for patients with NASH.

Despite these limitations, the strength of our analysis is its large sample size that estimates outcomes at the national level. Our study design with case control matching is another strength as it theoretically adjusts for confounding factors. Large prospective studies on long-term liver-related complications in AIH patients with BS are needed to further explore the impact of weight loss induced by BS on liver-related complications.

## 5. Conclusion

To date, there are limited studies on the relationship between weight loss induced by BS and AIH. This is the first national database study to explore the effects of BS on in-patient mortality and liver-related complications. Our study showed BS was an independent risk factor for ascites and hepatic encephalopathy but an independent protective factor against in-patient mortality. The AIH patients who underwent BS showed signs of decompensated liver disease, but overall improved in-patient mortality. Therefore, it will be interesting to determine the short and long-term effects of BS on hepatic fibrosis and systemic inflammation in these patients.

## Author contributions

**Conceptualization:** Catherine J Choi, Sushil Ahlawat.
**Data curation:** Catherine J Choi, Aditya Uppuluri, Reza Hashemipour.
**Formal analysis:** Catherine J Choi, Aldo Barajas-Ochoa, Aditya Uppuluri, Reza Hashemipour.
**Investigation:** Catherine J Choi.
**Methodology:** Catherine J Choi, Aldo Barajas-Ochoa.
**Resources:** Yi Jiang, Umair Nasir.
**Supervision:** Sushil Ahlawat.
**Writing – original draft:** Catherine J Choi, Aldo Barajas-Ochoa, Grace Ro.
**Writing – review & editing:** Catherine J Choi, Aditya Uppuluri, Grace Ro, Yi Jiang, Umair Nasir.

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