# Impact of barometric pressure on adhesive small bowel obstruction: A retrospective study

**Yuta Yamamoto** ( yyamamoto@shinshu-u.ac.jp )
Shinshu University School of Medicine https://orcid.org/0000-0003-1225-2240

**Yusuke Miyagawa**
Shinshu University School of Medicine

**Masato Kitazawa**
Shinshu University School of Medicine

**Hiokazu Tanaka**
Shinshu University School of Medicine

**Masatsugu Kuroiwa**
Shinshu University School of Medicine

**Nao Hondo**
Shinshu University School of Medicine

**Makoto Koyama**
Shinshu University School of Medicine

**Satoshi Nakamura**
Shinshu University School of Medicine

**Shigeo Tokumaru**
Shinshu University School of Medicine

**Futoshi Muranaka**
Shinshu University School of Medicine

**Yuji Soejima**
Shinshu University School of Medicine

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## Abstract

# Background

Adhesive small bowel obstruction (ASBO) is one of the most common causes of postoperative morbidity. According to Boyle's law, decreased barometric pressure causes the volume of intestinal gas to expand. We aimed to elucidate the relationship between barometric pressure and ASBO.

# Methods

We divided 215 admissions of 120 patients with ASBO into three groups: fasting group with response to fasting (n = 51); decompression group with successful treatment of gastrointestinal decompression (n = 104); and surgery group that required emergency or elective surgery to treat ASBO (n = 60). We compared and examined clinical backgrounds, findings on admission, and barometric pressure during the peri-onset period (29 days: from 14 days before to 14 days after the onset of ASBO).

# Results

There were significant difference among the three groups in gender, history of ASBO, hospital length of stay, and barometric pressure on the onset day of ASBO. Barometric pressure on the onset day was significantly higher in the fasting group than in the decompression group ($p = 0.005$). During pre-onset day 5 to post-onset day 2, fluctuations in the barometric pressure in the fasting and decompression groups showed reciprocal changes with a symmetrical axis overlapping the median barometric pressure in Matsumoto City, and the fluctuations tapered over time after onset. In the fasting group, the barometric pressure on the onset day was significantly higher than that on pre-onset days 14, 11, 7, 4, 3, 2; post-onset days 3, 10; and the median pressure in Matsumoto City. Conversely, in the decompression group, the barometric pressure on the onset day was lower than that on pre-onset days 14, 5 – 2; post-onset days 1, 2, 7, 8, 11, 13, 14; and the median pressure in Matsumoto City. In the surgery group, the barometric pressure on the onset day was equivalent to those on the other days.

# Conclusion

ASBO with response to conservative treatment is vulnerable to barometric pressure. Additionally, ASBO successfully treated with fasting and decompression is associated with a different barometric pressure on the onset day and reciprocal fluctuations in the barometric pressure during the peri-onset period.

## Background

Adhesive small bowel obstruction (ASBO) is one of the most common causes of postoperative morbidity. It occurs in 3% of all laparotomies; 1% of patients undergo surgery for ASBO within 1 year after undergoing laparotomy [1–3]. Patients with previous abdominal surgery sometimes developed ASBO despite being careful to consume easily digestible food and chew well. Although climate changes have been previously reported to be associated with the onset of ASBO [4], it has remained unclear whether any factor other than diet could induce ASBO. The management of ASBO is based on clinical parameters including history and physical examination, laboratory analysis, and computed tomography (CT) imaging. Recent advances in diagnostic imaging technology of contrast CT have enabled us to accurately identify the findings that indicate intestinal ischemia, including reduced enhanced bowel wall, mesenteric edema, and the closed-loop sign [5–7]. Some patients with ASBO are successfully treated with only fasting, whereas others require intestinal decompression through nasogastric tube placement (NGT) and long-tube placement (LT). When conservative management fails or patients show signs indicating intestinal ischemia, surgical intervention is necessary. Nevertheless, discrimination of diverse ASBO in respect to the response to each treatment remains unclear.

Several diseases have been reported to be related to barometric pressure, including acute ischemic stroke [8], benign paroxysmal positional vertigo [9], and migraine headache [10]. According to Boyle’s law, it is assumed that the decreased barometric pressure would cause the volume of intestinal gas to expand. Nevertheless, the relationships between ASBO and barometric pressure have not been clarified yet. Therefore, we performed this study to determine the relationship between barometric pressure and ASBO.

## Methods

# Patients and study design

This retrospective cohort study included patients with ASBO who were admitted to Shinshu University Hospital from November 2007 to August 2019. ASBO was diagnosed by clinical symptoms including abdominal pain, nausea, and vomiting, and radiological imaging that demonstrated a dilated small intestine with a diameter > 2.5 cm. During the inclusion period, 141 patients (236 admissions) with ASBO were admitted to our department. We excluded 21 admissions of 21 patients who had no history of abdominal surgery. Our final study group consisted of 120 patients (215 admissions). They were divided into three groups: fasting group with response to fasting (n = 51); decompression group with successful treatment of gastrointestinal decompression (n = 104); and surgery group that required emergency or elective surgery to treat ASBO (n = 60) (Fig. 1). We compared and examined clinical backgrounds, findings on admission, and barometric pressure during the peri-onset period (29 days: from 14 days before to 14 day after the onset of ASBO). With regard to the management of ASBO, intravenous fluids were administered in all patients. Initially, we assessed the requirement of emergency surgery including strangulation and ischemia or congestion of the small intestine. When these findings were not confirmed, the patients were judged to be candidates for conservative treatment. In general, patients with improving clinical symptoms on admission were managed with fasting in the first 24–48 hours. When the obstruction did not improve, they were treated with gastrointestinal decompression including NGT, hyperbaric oxygen therapy (HBO), and LT. Other candidates for conservative treatment with active symptoms were treated with gastrointestinal decompression at first. In cases in which the obstruction continued for more than 1 week or repeated after diet resumption, we performed elective surgery.

Shinshu University Hospital is located in Matsumoto City, Nagano prefecture, almost in the center of Honshu, a main island in Japan, at an altitude of 610 meters. Data regarding daily average barometric pressure in Matsumoto City were obtained from the website of the Japan Meteorological Agency (URL:www.jma.go.jp/jma/index.html).

## Statistical analysis

Statistical analysis was performed using the Statistical Package for Social Sciences version 23.0 (SPSS; Chicago, IL, USA). Demographic data are presented with descriptive statistics. Non-parametric data are presented as medians with interquartile ranges. With regard to barometric pressure in each group during the peri-onset period, parametric and non-parametric data were intermingled, so we considered all barometric pressure as non-parametric data. Comparisons between qualitative variables were performed using the chi-square test. The Kruskal-Wallis test was used to compare non-parametric data among the three groups. If a significant difference ($p < 0.05$) was shown, the Mann-Whitney test with Bonferroni correction for multiple comparisons was used to perform multiple comparisons. The Wilcoxon matched-pairs signed-rank test was used to compare the median barometric pressure on the onset day to that on another day in each group. One-sample Wilcoxon signed rank test was used to determine whether a median barometric pressure on a certain day in each group differed from the median barometric pressure in Matsumoto City during November 2007 to August 2019 (943.4 hPa). All tests were two-tailed, and differences with a $p$-value of < 0.05 were considered statistically significant.

## Results

Patients' characteristics in each group are shown in Additional file 1. There were significant differences among the three groups in terms of gender ($p = 0.007$), history of ASBO ($p < 0.001$), hospital length of stay (LOS) ($p < 0.001$), and barometric pressure on pre-onset day 1 ($p = 0.049$) and ASBO onset day ($p = 0.006$). As a result of the Mann-Whitney test with Bonferroni correction, LOS was shorter in the fasting group than in the decompression ($p = 0.002$) and surgery groups ($p < 0.001$), and LOS was shorter in the decompression group than in the surgery group ($p < 0.001$). Barometric pressure on the onset day was significantly higher in the fasting group than in the decompression group ($p = 0.005$) (Table 1).

With regard to fluctuation in barometric pressure in each subgroup during the peri-onset period, the line graph showed reciprocal change in the fasting and decompression groups, in particular from pre-onset day 5 to post-onset day 2, with a symmetrical axis overlapping the median barometric pressure in Matsumoto City from November 2007 to August 2019 (Fig. 2). In line with this, the barometric pressure on the onset day was significantly higher than those on pre-onset days 4 – 2 in the fasting group, whereas the pressure on the onset day was lower than those on pre-onset days 5 – 2 in the decompression group (Table 2). Additionally, these two lines tapered over time after onset. Compared to the median barometric pressure in Matsumoto City, the pressures on the onset day and post-onset day 1 were significantly higher in the fasting group ($p$ = 0.011 and 0.008, respectively), whereas that on the onset day was significantly lower in decompression group ($p$ = 0.049) (Table 3). These findings showed that ASBO, which responds to fasting and decompression, is associated with reciprocal fluctuations in barometric pressure like the sine curve during the peri-onset period, in particular from pre-onset day 5 to post-onset day 2, with the amplitude representing significant change in the barometric pressure on the onset day. However, in the surgery group, the barometric pressure on the onset day was equivalent to those on the other days (Table 2) and the median barometric pressure in Matsumoto City (Table 3). Together, these data suggest the possible impact of barometric pressure on the etiology and successful conservative treatment of ASBO.

# Discussion

We found that barometric pressure were associated with ASBO which responded to conservative treatment during the peri-onset period. In detail, barometric pressure on the onset day was significantly higher in the fasting group than in the decompression group, and barometric pressures in both groups were significantly different from the median pressure in Matsumoto City. Additionally, the fluctuations in barometric pressure during the peri-onset period in the two groups were significant and reciprocal. When considering the unknown etiology and difficulty of predicting the response and failure of conservative management, these results have significant importance because they suggest the possible impact of barometric pressure on the etiology and treatment of ASBO.

In Japan, HBO is regarded as an optional treatment in many emergency diseases including carbon monoxide poisoning, sudden sensorineural hearing loss, central retinal vein occlusion, and ASBO, although few clinical trials have addressed its role in ASBO [11–13]. Based on Boyle's law, decreased barometric pressure causes intestinal gas volume to expand, and conversely, increased pressure causes intestinal decompression. However, considering that it remains unclear as to whether the effect of HBO on ASBO is cellular, biochemical, or physical in nature [14, 15], it is difficult to explain the mechanism of our result. In an experiment on dogs that used intestinal closed loop obstructions, Cross reported that, as barometric pressure increased, the absorption of gas from the closed loop obstructions increased in dogs breathing ambient air, not breathing high concentration oxygen [16]. In that experiment, an average of 10.4% of the injected air diffused from the loops after 24 hours at 1 atmosphere pressure, and 27.0% was absorbed after same hours at 2 atmosphere pressures, with an increase of 16.6%. Even though natural variation of barometric pressure may have a small impact on the intestinal absorption of gas, the influence of the pressure on ASBO does not simply depend on the physical properties of intestinal gas.

There are several limitations to this study. First, it was a single-center study and therefore may be subject to selection bias. Second, the number of patients was too small to adequately determine the relationship between barometric pressure and ASBO, and this may result in a beta error. Third, the parameter we used did not perfectly represent the exact barometric pressure at the time and place in patients with ASBO. In particular, not all patients lived in Matsumoto City, and the barometric pressure we used in this study was a mean value derived every 24 hours, and did not consider circadian change. Finally, although we found that barometric pressure affected ASBO in some way, it is still uncertain whether the pressure affects the etiology or treatment, or both.

Therefore, prospective multi-center studies incorporating larger patient populations are needed to draw definite conclusions on whether barometric pressure is associated with the etiology and treatment of ASBO.

# Conclusions

Barometric pressure on the onset day was significantly higher in the fasting group than in the decompression group. Additionally, the fluctuations in barometric pressure during the peri-onset period in the two groups were significant and reciprocal.

# List Of Abbreviations

ASBO, adhesive small bowel obstruction; CT, computed tomography; NGT, nasogastric tube placement; LT, long-tube placement; HBO, hyperbaric oxygen therapy; LOS, length of stay

# Declarations

### Ethics approval and consent to participate

The study was conducted in accordance to the ethical guidelines of the 1975 Declaration of Helsinki and approved by the Ethical Committee of Shinshu University Hospital. Informed consent was obtained from each patient included in the study.

### Consent for publication

Not applicable.

### Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author or upon reasonable request.

### Competing interests

The authors declare that they have no competing interests.


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### Author contributions

YY wrote the paper, designed the study, performed the research, and acquired the data. All authors take responsibility for the integrity of the data and the accuracy of the data analysis. YM and YS revised the manuscript. All authors read and approved the final manuscript.


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## References


1. Hiki N, Takeshita Y, Kubota K, Tsuji E, Yamaguchi H, Shimizu N, et al. A seasonal variation in the onset of postoperative adhesive small bowel obstruction is related to changes in the climate. Dig Liver Dis. 2004;36:125–9.
2. ten Broek RP, Issa Y, van Santbrink EJ, Bouvy ND, Kruitwagen RF, Jeekel J, et al. Burden of adhesion in abdominal and pelvic surgery: systematic review and met-analysis. BMJ. 2013;347:f5588.
3. Menzies D. Peritoneal adhesions. Incidence, cause, and prevention. Surg Annu. 1992;24:27–45.
4. Ellis H. The clinical significance of adhesions: focus on intestinal obstruction. Eur J Surg Suppl. 1997;(577):5–9.
5. Balthazar EJ, Birnbaum BA, Megibow AJ, Gordon RB, Whelan CA, Hulnick DH. Closed-loop and strangulating intestinal obstruction: CT signs. Radiology. 1992;185:769–75.
6. Balthazar EJ, Liebeskind ME, Macari M. Intestinal ischemia in patients in whom small bowel obstruction is suspected: evaluation of accuracy, limitations, and clinical implications of CT in diagnosis. Radiology. 1997;205:519–22.
7. Hayakawa K, Tanikake M, Yoshida S, Yamamoto A, Yamamoto E, Morimoto T. CT findings of small bowel strangulation: the importance of contrast enhancement. Emerg Radiol. 2013;20:3–9.
8. Guan W, Clay SJ, Sloan GJ, Pretlow LG. Effects of barometric pressure and temperature on acute ischemic stroke hospitalization in Augusta, GA. Transl Stroke Res. 2018. doi:10.1007/s12975-018-0640-0.
9. Korpon JR, Sabo RT, Coelho DH. Barometric pressure and the incidence of benign paroxysmal positional vertigo. Am J Otolaryngol. 2019;40:641–4.
10. Kimoto K, Aiba S, Takashima R, Suzuki K, Takekawa H, Watanabe Y, et al. Influence of barometric pressure in patients with migraine headache. Intern Med. 2011;50:1923–8.
11. Ambiru S, Furuyama N, Kimura F, himizu H, Yoshidome H, Miyazaki M, et al. Effect of hyperbaric oxygen therapy on patients with adhesive intestinal obstruction associated with abdominal surgery who have failed to respond to more than 7 days of conservative treatment. Hepatogastroenterology. 2008;55:491–5.

12. Fukami Y, Kurumiya Y, Mizuno K, Sekoguchi E, Kobayashi S. Clinical effect of hyperbaric oxygen therapy in adhesive postoperative small bowel obstruction. Br J Surg. 2014;101:433–7.
13. Fukami Y, Kobayashi S, Sekoguchi E, Kurumiya Y. Randomized controlled trial of hyperbaric oxygen therapy in adhesive postoperative small bowel obstruction. Langenbecks Arch Surg. 2018;403:555–9.
14. Tibbles PM, Edelsberg JS. Hyperbaric-oxygen therapy. N Engl J Med. 1996;334:1642–8.
15. Leach RM, Rees PJ, Wilmshurst P. Hyperbaric oxygen therapy. BMJ. 1998;317:1140–3.
16. Cross FS. The effect of increased atmospheric pressures and the inhalation of 95% oxygen and helium-oxygen mixtures on the viability of the bowel wall and the absorption of gas in closed-loop obstructions. Surgery. 1954;36:1001–6.

# Tables

**Table 1** *P*-values of the Mann-Whitney test with Bonferroni correction for multiple comparisons

| | Fasting vs Decompression | Fasting vs Surgery | Decompression vs Surgery |
|---|---|---|---|
| Hospital length of stay | 0.002* | <0.001* | <0.001* |
| Barometric pressure | | | |
| Pre-onset day 1 | 0.052 | 1.000 | 0.475 |
| Onset day | 0.005* | 0.553 | 0.239 |

Asterisks indicate statistical significance. vs.,versus.

**Table 2** Comparison of the barometric pressure between onset and another day in each group

| | Fasting group | | | Decompression group | | | Surgery group | | |
|---|---|---|---|---|---|---|---|---|---|
| | Barometric pressure (hPa) | Difference (hPa) | *p*-value | Barometric pressure (hPa) | Difference (hPa) | *p*-value | Barometric pressure (hPa) | Difference (hPa) | *p*-value |
| Pre-onset day 14 | 943.6 | -1.6 | 0.029* | 943.2 | 1.2 | 0.031* | 943.6 | -1.5 | 0.363 |
| Pre-onset day 13 | 943.6 | -1.6 | 0.109 | 943.5 | 1.5 | 0.214 | 944.1 | -1.0 | 0.988 |
| Pre-onset day 12 | 943.9 | -1.3 | 0.097 | 943.2 | 1.2 | 0.160 | 943.7 | -1.4 | 0.877 |
| Pre-onset day 11 | 944.9 | -0.3 | 0.047* | 943.1 | 1.1 | 0.240 | 943.3 | -1.8 | 0.491 |
| Pre-onset day 10 | 944.7 | -0.5 | 0.211 | 944.0 | 2.0 | 0.080 | 943.9 | -1.2 | 0.697 |
| Pre-onset day 9 | 944.9 | -0.4 | 0.609 | 944.4 | 2.3 | 0.064 | 943.9 | -1.2 | 0.836 |
| Pre-onset day 8 | 945.0 | -0.2 | 0.228 | 944.4 | 2.4 | 0.068 | 943.4 | -1.7 | 0.752 |
| Pre-onset day 7 | 943.3 | -1.9 | 0.041* | 944.2 | 2.2 | 0.103 | 943.6 | -1.5 | 0.977 |
| Pre-onset day 6 | 943.0 | -2.3 | 0.087 | 943.9 | 1.9 | 0.159 | 944.0 | -1.1 | 0.563 |
| Pre-onset day 5 | 943.7 | -1.5 | 0.157 | 943.8 | 1.8 | 0.027* | 944.5 | -0.6 | 0.683 |
| Pre-onset day 4 | 943.3 | -1.9 | 0.038* | 944.4 | 2.4 | 0.003* | 943.9 | -1.2 | 0.546 |
| Pre-onset day 3 | 941.3 | -3.9 | <0.001* | 944.2 | 2.2 | 0.009* | 943.8 | -1.3 | 0.780 |
| Pre-onset day 2 | 941.9 | -3.4 | 0.013* | 943.5 | 1.5 | 0.006* | 943.9 | -1.2 | 0.768 |
| Pre-onset day 1 | 944.6 | -0.6 | 0.283 | 942.2 | 0.2 | 0.322 | 943.8 | -1.3 | 0.877 |
| Onset day | 945.2 (Control) | - | - | 942.0 (Control) | - | - | 945.1 (Control) | - | - |
| Post-onset day 1 | 945.3 | 0.1 | 0.970 | 943.6 | 1.5 | 0.024* | 944.1 | -1.0 | 0.924 |
| Post-onset day 2 | 943.9 | -1.3 | 0.232 | 943.4 | 1.3 | 0.026* | 944.6 | -0.5 | 0.282 |
| Post-onset day 3 | 943.9 | -1.3 | 0.023* | 944.2 | 2.1 | 0.062 | 944.4 | -0.7 | 0.688 |
| Post-onset day 4 | 943.3 | -2.0 | 0.063 | 943.5 | 1.5 | 0.167 | 943.9 | -1.2 | 0.724 |
| Post-onset day 5 | 944.7 | -0.5 | 0.066 | 943.5 | 1.5 | 0.287 | 944.0 | -1.1 | 0.831 |
| Post-onset day 6 | 943.8 | -1.5 | 0.060 | 943.8 | 1.8 | 0.192 | 944.8 | -0.3 | 0.473 |
| Post-onset day 7 | 944.4 | -0.9 | 0.065 | 944.4 | 2.3 | 0.019* | 943.6 | -1.5 | 0.686 |
| Post-onset day 8 | 944.7 | -0.6 | 0.130 | 944.1 | 2.0 | 0.029* | 943.7 | -1.4 | 0.836 |
| Post-onset day 9 | 944.4 | -0.8 | 0.087 | 943.8 | 1.8 | 0.171 | 945.1 | 0.0 | 0.184 |
| Post-onset day 10 | 944.0 | -1.3 | 0.042* | 943.1 | 1.0 | 0.067 | 945.1 | 0.0 | 0.132 |
| Post-onset day 11 | 945.6 | 0.4 | 0.357 | 943.0 | 1.0 | 0.013* | 944.2 | -0.9 | 0.949 |
| Post-onset day 12 | 944.6 | -0.6 | 0.398 | 943.8 | 1.8 | 0.051 | 941.8 | -3.3 | 0.137 |
| Post-onset day 13 | 945.1 | -0.1 | 0.302 | 944.4 | 2.4 | 0.003* | 941.9 | -3.2 | 0.156 |
| Post-onset day 14 | 943.6 | -1.6 | 0.176 | 945.3 | 3.3 | <0.001* | 944.4 | -0.7 | 0.592 |

Asterisks indicate statistical significance.

Table 3 Comparison of the barometric pressure in the study groups and the median barometric pressure in Matsumoto City (943.4 hPa)

| | Fasting group | | Decompression group | | Surgery group | |
|---|---|---|---|---|---|---|
| | Barometric pressure (hPa) | *p*-value | Barometric pressure (hPa) | *p*-value | Barometric pressure (hPa) | *p*-value |
| Pre-onset day 14, median (IQR) | 943.6 (939.0-947.0) | 0.564 | 943.2 (940.0-948.2) | 0.447 | 943.6 (938.9-946.4) | 0.448 |
| Pre-onset day 13, median (IQR) | 943.6 (939.2-948.6) | 0.970 | 943.5 (939.1-947.4) | 0.876 | 944.1 (940.6-946.0) | 0.651 |
| Pre-onset day 12, median (IQR) | 943.9 (940.1-947.5) | 0.626 | 943.2 (940.1-946.6) | 0.928 | 943.7 (941.2-947.2) | 0.383 |
| Pre-onset day 11, median (IQR) | 944.9 (938.9-947.3) | 0.899 | 943.1 (940.0-946.4) | 0.662 | 943.3 (940.1-947.2) | 0.836 |
| Pre-onset day 10, median (IQR) | 944.8 (940.7-948.7) | 0.158 | 944.0 (940.3-947.4) | 0.588 | 943.9 (939.5-948.4) | 0.766 |
| Pre-onset day 9, median (IQR) | 945.1 (940.7-948.5) | 0.076 | 944.4 (939.4-947.4) | 0.517 | 943.9 (939.9-947.3) | 0.642 |
| Pre-onset day 8, median (IQR) | 945.0 (941.0-947.1) | 0.212 | 944.4 (939.4-947.8) | 0.513 | 943.4 (940.6-947.8) | 0.303 |
| Pre-onset day 7, median (IQR) | 943.3 (938.7-946.7) | 0.981 | 944.2 (940.1-947.6) | 0.433 | 943.6 (940.2-947.1) | 0.648 |
| Pre-onset day 6, median (IQR) | 943.1 (938.7-948.3) | 0.910 | 943.9 (939.2-947.8) | 0.879 | 944.0 (940.6-947.2) | 0.245 |
| Pre-onset day 5, median (IQR) | 943.7 (939.4-947.1) | 0.761 | 943.8 (939.5-948.7) | 0.521 | 944.5 (939.7-946.9) | 0.664 |
| Pre-onset day 4, median (IQR) | 943.4 (938.7-947.4) | 0.968 | 944.4 (940.0-947.7) | 0.181 | 943.9 (940.4-948.4) | 0.433 |
| Pre-onset day 3, median (IQR) | 941.3 (936.8-946.6) | 0.073 | 944.2 (940.2-948.5) | 0.179 | 943.8 (938.7-948.1) | 0.889 |
| Pre-onset day 2, median (IQR) | 942.0 (939.3-947.6) | 0.746 | 943.5 (940.2-947.7) | 0.357 | 943.9 (938.0-948.2) | 0.892 |
| Pre-onset day 1, median (IQR) | 944.6 (940.9-949.6) | 0.111 | 942.2 (938.9-946.2) | 0.095 | 943.8 (939.9-947.4) | 0.656 |
| Onset day, median (IQR) | 945.2 (941.9-949.9) | 0.010* | 942.0 (937.3-946.8) | 0.047* | 945.1 (938.5-947.6) | 0.642 |
| Post-onset day 1, median (IQR) | 945.3 (940.3-950.4) | 0.024* | 943.6 (938.4-946.7) | 0.498 | 944.1 (939.7-947.6) | 0.538 |
| Post-onset day 2, median (IQR) | 943.9 (941.0-949.0) | 0.131 | 943.4 (939.6-948.1) | 0.827 | 944.6 (940.7-948.3) | 0.166 |
| Post-onset day 3, median (IQR) | 944.0 (938.1-947.5) | 0.609 | 944.2 (939.0-947.4) | 0.851 | 944.4 (940.7-947.2) | 0.317 |
| Post-onset day 4, median (IQR) | 943.3 (938.4-947.7) | 0.786 | 943.5 (939.6-947.6) | 0.981 | 943.9 (939.7-946.9) | 0.958 |
| Post-onset day 5, median (IQR) | 945.0 (938.7-947.6) | 0.929 | 943.5 (939.3-947.4) | 0.811 | 944.0 (938.7-947.7) | 0.839 |
| Post-onset day 6, median (IQR) | 944.0 (941.0-946.4) | 0.677 | 943.8 (938.7-946.7) | 0.626 | 944.8 (939.4-948.8) | 0.284 |
| Post-onset day 7, median (IQR) | 944.4 (941.4-947.7) | 0.592 | 944.4 (940.2-947.2) | 0.185 | 943.7 (939.9-949.3) | 0.522 |
| Post-onset day 8, median (IQR) | 944.9 (939.6-949.0) | 0.494 | 944.1 (940.3-947.6) | 0.290 | 943.7 (939.3-947.9) | 0.632 |
| Post-onset day 9, median (IQR) | 944.6 (938.3-947.6) | 0.948 | 943.8 (939.8-947.0) | 0.957 | 945.1 (940.6-948.6) | 0.095 |
| Post-onset day 10, median (IQR) | 944.0 (937.2-948.9) | 0.859 | 943.1 (940.0-946.7) | 0.896 | 945.1 (939.3-948.5) | 0.154 |
| Post-onset day 11, median (IQR) | 945.6 (938.9-949.2) | 0.197 | 943.0 (940.5-947.0) | 0.897 | 944.2 (937.8-948.8) | 0.721 |
| Post-onset day 12, median (IQR) | 944.6 (940.7-949.6) | 0.095 | 943.8 (939.2-947.9) | 0.953 | 941.8 (937.9-948.8) | 0.096 |
| Post-onset day 13, median (IQR) | 945.1 (940.2-948.2) | 0.298 | 944.4 (939.8-948.3) | 0.225 | 941.9 (938.6-945.5) | 0.101 |
| Post-onset day 14, median (IQR) | 943.6 (940.1-947.8) | 0.466 | 945.3 (940.1-949.6) | 0.013* | 944.4 (940.9-947.6) | 0.096 |

Asterisks indicate statistical significance. IQR, interquartile range.

# Additional Files

**File name:** Additional file 1

**File format: .docx**

**Title of data:** Patients' demographics and summary of data

**Description of data:** Patients' demographics and summary of data by study group.

# Figures

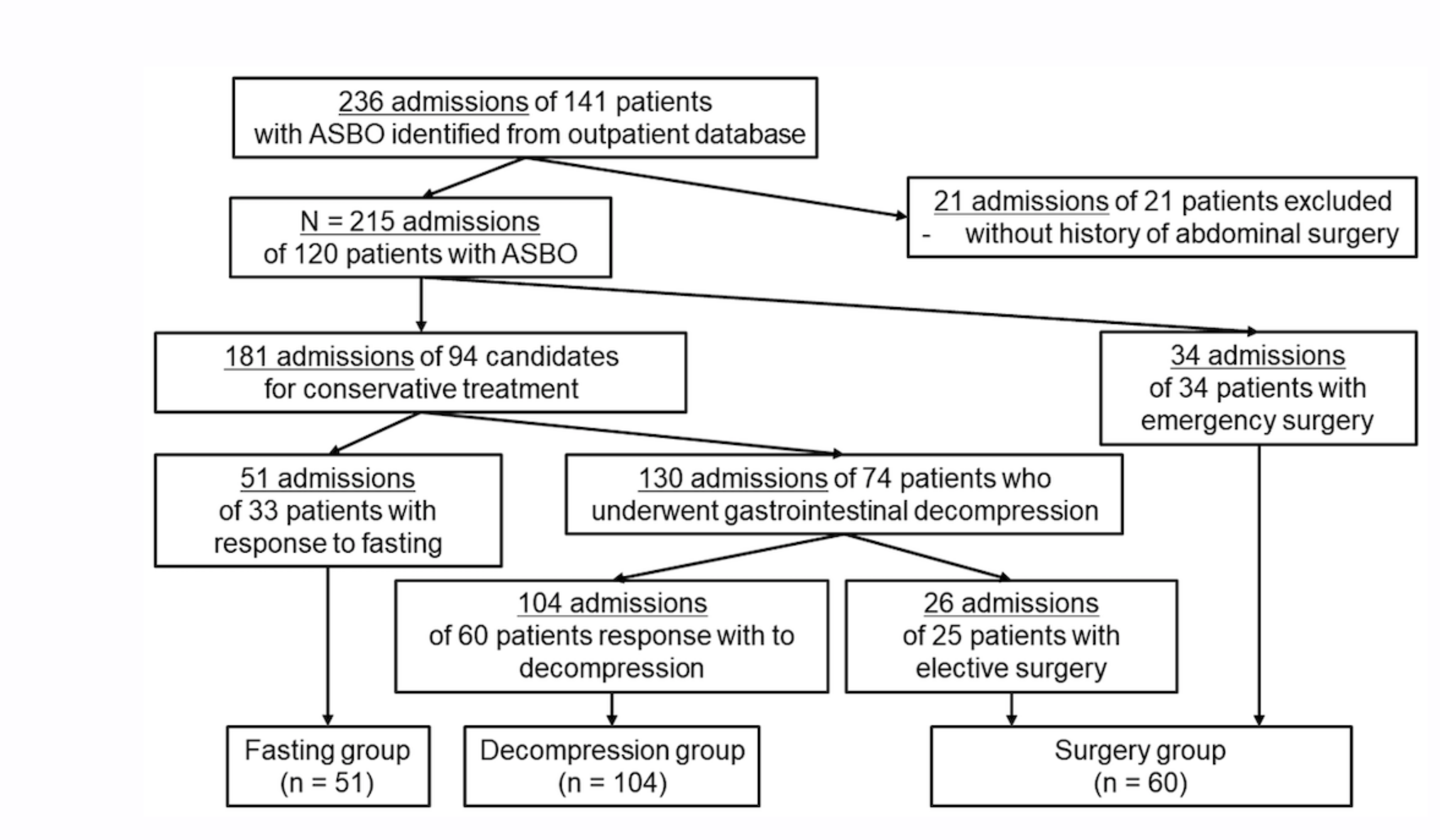


**Figure 1**

Flowchart of the selection of study groups. ASBO, adhesive small bowel obstruction.

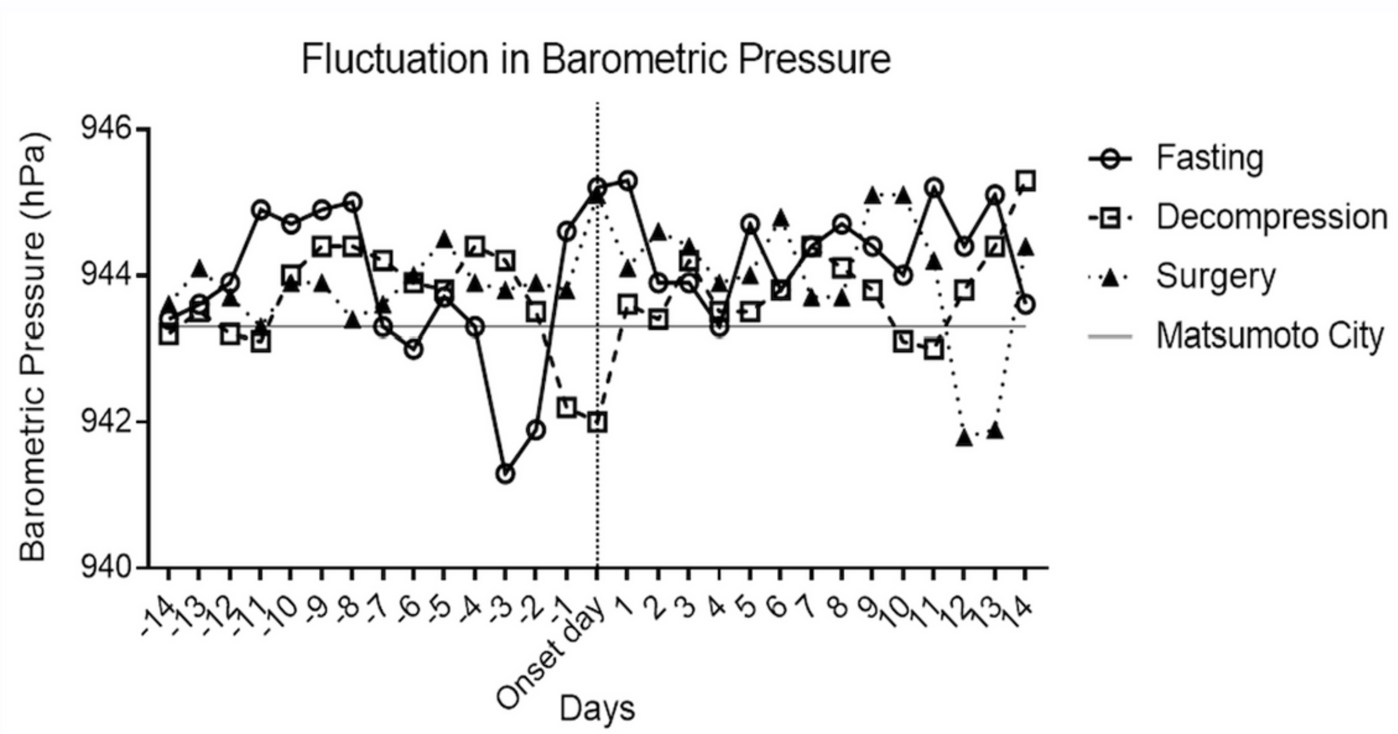


**Figure 2**

Fluctuations in the median barometric pressure in each subgroup during the peri-onset period. A horizontal line on 943.4 hPa means the median barometric pressure in Matsumoto City from November 2007 to August 2019.

# Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- supplement6.docx