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Comparison of robotic and laparoscopic lateral transperitoneal adrenalectomies

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Purpose: This study aimed to compare the intraoperative and postoperative outcomes between robotic and laparoscopic transperitoneal adrenalectomies.
Methods: In this retrospective study, 93 patients underwent adrenalectomy using 2 surgical modalities: 45 patients underwent adrenalectomy using the da Vinci Xi system (robotic group), and 48 patients using laparoscopic devices (laparoscopic group). We compared the operation time, intraoperative bleeding, and hospital stay according to the surgical modality and tumor characteristics.
Results: There were no significant differences in the operative time (P = 0.827), hospital stay (P = 0.177), and intraoperative bleeding (P = 0.174) between the groups. However, the robotic group showed a lower coefficient of variation in total operative time than that of the laparoscopic group (100.6 ± 23.3 minutes *vs*. 101.9±32.7 minutes, 0.230 *vs*. 0.321). When divided into 2 subgroups based on the tumor size (<3 cm and ≥3 cm), the robotic group with a tumor sized >3 cm had a shorter operative time than that of the laparoscopic group (P = 0.032). The robotic group also had fewer cases of intraoperative bleeding (P = 0.034).
Conclusions: Compared to the laparoscopic transperitoneal adrenalectomy, the robotic one achieved a lower deviation in total operative time and showed less bleeding and a shorter operative time, especially for tumors sized >3 cm.
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Key Words: Adrenalectomy, Cushing syndrome, Hyperaldosteronism, Pheochromocytoma, Robot surgical procedures

INTRODUCTION

Laparoscopic adrenalectomy is the standard treatment for minimally invasive adrenal tumor resection. Robotic adrenal surgery has recently attracted interest due to the introduction of the da Vinci system (Intuitive Surgical, Inc). Several series of robotic adrenalectomies have been reported, demonstrating the safety and feasibility of the procedure as well as potential advantages over laparoscopy owing to the unique features of the robotic system, such as 3-dimensional (3D) vision and the EndoWrist technique [1].

Brandao et al. [2] reported that robotic adrenalectomy can be performed safely and effectively with a shorter operative time and provides potential advantages, such as shorter hospitalization, less blood loss, lower occurrence of postoperative complications, elimination of surgeon tremors, and reduced surgeon fatigue intraoperatively. These advantages are particularly important for improving surgical outcomes in patients with large tumors and/or obesity [3,4].

The present study aimed to evaluate the technical feasibility of robotic transperitoneal adrenalectomy by comparing its surgical outcomes to those of laparoscopic transperitoneal adrenalectomy.

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METHODS

This retrospective study was approved by the Institutional Review Board of Korea University Ansan Hospital (No. 2023AS0121). It was performed in accordance with the Declaration of Helsinki and written informed consent was waived due to its retrospective nature.

Patients

After obtaining Institutional Review Board approval, we conducted a retrospective review of the medical records of all patients who underwent laparoscopic or robotic adrenalectomies between January 2018 and June 2022, with the aim to evaluate the surgical outcomes. During this period, 98 patients underwent adrenalectomies using a transperitoneal approach. Two groups were formed: the robotic and laparoscopic groups. Five patients were excluded. One patient had left adrenal metastasis invading the renal vein due to lung cancer, requiring a nephrectomy. Consequently, an open conversion procedure was performed. Another patient underwent hand-assisted laparoscopic surgery due to the adenoma size exceeding 7 cm. One patient had excessive intraperitoneal adhesions, and 2 patients collaborated with other divisions, which could have affected the surgical outcomes (Fig. 1). All adrenalectomies were performed by a single surgeon (YWC) to ensure consistency in the surgical techniques. The clinicopathological characteristics of the patients were recorded, including age, sex, body mass index (BMI), tumor size, tumor location, pathological results, operative time, estimated blood loss, complications, and length of hospital stay.

Positioning and port placement

A da Vinci Xi robotic system was used for all robotic adrenalectomies. Robotic and laparoscopic surgeries were performed using the transperitoneal approach, with the patient in the lateral decubitus position. For right adrenalectomies, the patient was placed in the left lateral decubitus position, whereas for left adrenalectomies, the patient was placed in the right lateral decubitus position. Three ports were used for left laparoscopic and robotic adrenalectomies, and 4 ports were used for right laparoscopic and robotic adrenalectomies.

During the procedure, a camera port (8 mm for robotic and 12 mm for laparoscopic adrenalectomy) was placed on the rectal margin at the level of the umbilicus. In addition, for robotic adrenalectomies, a glove port was used to insert the cameras and assistant devices. After pneumoperitoneum was established, another port (8 mm for the robotic and 5 mm for laparoscopic adrenalectomy) was placed on the posterior axillary line and rectus margin, 6–8 cm from the camera port, and another port (8 mm for the robotic and 5 mm for laparoscopic adrenalectomy) was placed at the midline in the epigastrium and hypogastrium. The robot was then docked, and trocars were placed (Fig. 2). In cases where right adrenalectomy was performed, whether laparoscopic or robotic surgery, an additional port was required to elevate the liver (Fig. 3). Therefore, an additional port was placed immediately below the xiphoid process (Fig. 2A).

Statistical analyses

All statistical analyses were performed using the IBM SPSS Statistics ver. 29.0 for Windows (IBM Corp.). Two-group comparisons were conducted using the chi-square test or Mann-Whitney U-test, as appropriate. The clinicopathological characteristics of age, sex, BMI, tumor size, and tumor location were compared between the robotic and laparoscopic groups using either Student t-test or the chi-square test, as appropriate. The surgical outcomes of operative time estimated blood loss, complications, and length of hospital stay were compared between the 2 groups using either the Mann-Whitney U-test or Fisher exact test, as appropriate. The results of each comparison are presented as mean ± standard deviation or number (percentage), as appropriate. The statistical significance was set

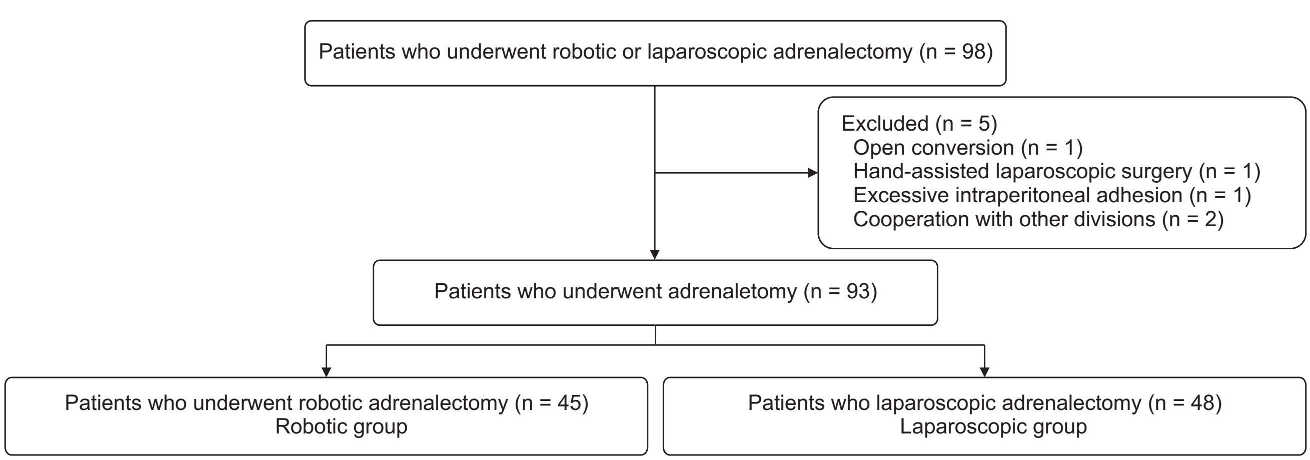

Fig. 1. Flow chart of the study population.

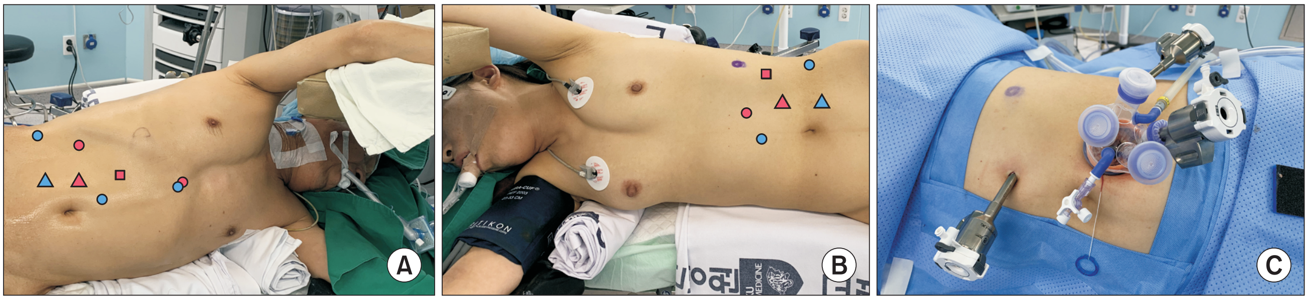

Fig. 2. (A) A photo showing the left lateral decubitus position and port placement for right adrenalectomy, (B) A photo showing the right lateral decubitus position and port placement for left adrenalectomy, (C) A photo showing the camera port replacement through the glove port in robotic adrenalectomy. Blue circles, 8 mm trocars for robotic devices; blue triangle, 8-mm trocar for a robotic camera; red circles, 5-mm trocars for left-handed laparoscopic device and liver-retractor; red triangle, 12-mm trocar for the laparoscopic camera; red square, right-handed laparoscopic device. Written informed consent was obtained from the patients for the publication of clinical images.

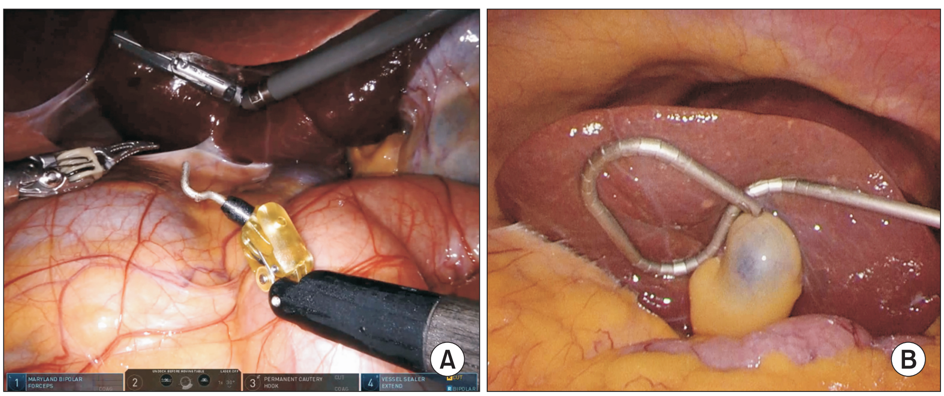

Fig. 3. Liver retraction (A) using a robotic device by a surgeon itself in robotic adrenalectomy, (B) using retractor by an assistant in laparoscopic adrenalectomy.

Table 1. Clinical pathological characteristics of patients who underwent robotic adrenalectomy or laparoscopic adrenalectomy

Characteristic	Robotic (n = 45)	Laparoscopic (n = 48)	P-value
No. of patients	45	48	
Age at operation (yr)	50.0 (25–70)	53.5 (28–76)	0.157
Sex			
Male	24 (53.3)	23 (47.9)	0.602
Female	21 (46.7)	25 (52.1)	
Body mass index (kg/m^2)	26.7 (19.6–38.8)	26.7 (17.4–48.6)	0.985
Tumor size (cm)	3.1 (1.0–8.5)	3.5 (1.5–8.7)	0.211
≤3.0	26 (57.8)	28 (58.3)	0.957
>3.0	19 (42.2)	20 (41.7)	
Tumor location			0.126
Right	20 (44.4)	14 (29.2)	
Left	25 (55.6)	34 (70.8)	
Clinical diagnosis			0.789
Nonfunctioning tumor	9 (20.0)	9 (18.8)	
Aldosteronism	11 (24.4)	8 (16.7)	
Cushing syndrome	10 (22.2)	15 (31.3)	
Pheochromocytoma	14 (31.1)	14 (29.2)	
Malignant	1 (2.2)	2 (4.2)	

Values are presented as number only, mean (range), or number (%).

at $P < 0.05$.

RESULTS

Table 1 shows the clinical characteristics of 93 patients who underwent adrenalectomy during the study period. Of these, 45 underwent robotic adrenalectomy and 48 underwent conventional laparoscopic adrenalectomy. The mean age of patients at the operation was 50.0 years in the robotic group and 53.5 years in the laparoscopic group ($P = 0.157$). There were no significant differences in sex distribution or BMI between the 2 groups. The mean tumor size was 3.1 cm in the robotic group and 3.5 cm in the laparoscopic group ($P = 0.211$), with similar percentages of tumors sized ≤3.0 cm and >3.0 cm in both groups. The distribution of tumor locations was not statistically significant ($P = 0.126$). There were no significant differences in clinical diagnosis between the 2 groups ($P = 0.789$). Most patients in both groups had nonfunctioning tumors, followed by aldosteronism and pheochromocytoma. Only a small number of patients had malignant tumors.

The intraoperative and postoperative outcomes of patients who underwent robotic or laparoscopic adrenalectomy were analyzed (Table 2). The mean operation time was similar between the 2 groups, with a mean of 100.6 ± 23.3 minutes in the robotic group and 101.9 ± 32.7 minutes in the laparoscopic group ($P = 0.827$). The postoperative hospital stay was also similar, with a mean of 3.6 days in the robotic group and 4.0 days in the laparoscopic group ($P = 0.177$). There were 11 cases of intraoperative bleeding in the robotic group and 18 cases in the laparoscopic group. However, this difference was not statistically significant ($P = 0.174$). Moreover, the coefficient of variation for time was lower in the robotic group than in the laparoscopic group (0.230 *vs.* 0.321) (Fig. 4).

A subgroup analysis was performed to evaluate the operative outcomes according to tumor location and size in patients who underwent robotic and laparoscopic adrenalectomies (Tables 3, 4). The analysis included various parameters, such as BMI, tumor size, operation time, postoperative hospital stay, and intraoperative bleeding. There were no significant differences between the 2 groups in any of the subgroups analyzed. The P-values for all comparisons were above 0.05, indicating that there were no statistically significant differences between the robotic and laparoscopic groups in any of the subgroups analyzed, except for patients with a tumor sized >3.0 cm. The study found that for patients with tumors sized >3 cm, the mean operative time was significantly shorter in the robotic group than in the laparoscopic group (93.8 minutes *vs.* 114.9 minutes, $P = 0.032$). Additionally, the incidence of intraoperative bleeding was significantly lower in the robotic group than in the laparoscopic group (26.3% *vs.* 60.0%, P =

Table 2. Operative outcomes according to surgical modalities

Variable	Robotic (n = 45)	Laparoscopic (n = 48)	P-value
Operative time (min)	100.6 (63–150)	101.9 (53–217)	0.827
Postoperative hospital stay (day)	3.6 (2–7)	4.0 (2–6)	0.177
Intraoperative bleeding	11 (24.4)	18 (37.5)	0.174

Values are presented as mean (range) or number (%).

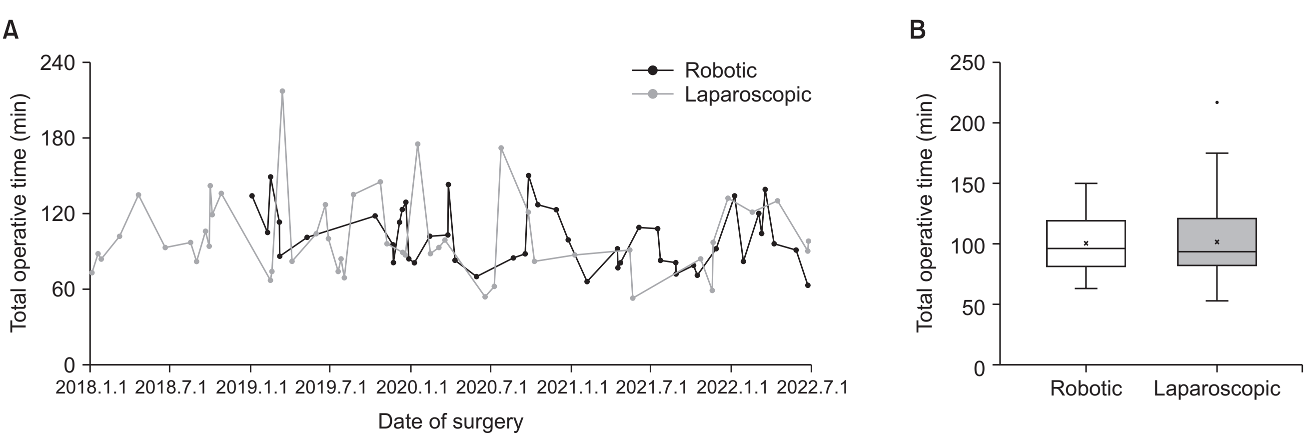

Fig. 4. (A) The duration, (B) average, and standard deviation of total operative time; the mean time of total operative time is not statistically different in both groups (100.6 ± 23.3 minutes *vs*. 101.9 ± 32.7 minutes, $p = 0.827$), but the coefficient of variation of time is lower in the robotic group than in the laparoscopic group (0.230 *vs*. 0.321).

Table 3. Operative outcomes according to tumor location

Variable	Right			Left		
	Robotic (n = 20)	Laparoscopic (n = 14)	P-value	Robotic (n = 25)	Laparoscopic (n = 34)	P-value
Body mass index (kg/m^2)	25.7 (19.6–36.2)	27.4 (17.4–45.7)	0.385	27.5 (20.7–38.8)	26.4 (18.6–48.6)	0.450
Tumor size (cm)	3.6 (1.7–8.5)	3.9 (1.7–8.0)	0.720	2.6 (1.0–5.0)	3.3 (1.5–8.7)	0.063
Operative time (min)	105.4 (70–139)	94.2 (51–142)	0.505	96.7 (63–150)	102.6 (53–217)	0.476
Postoperative hospital stay (day)	3.6 (2–7)	4.1 (2–6)	0.176	3.7 (2–6)	3.9 (2–6)	0.494
Intraoperative bleeding	5 (25.0)	5 (35.7)	0.500	6 (24.0)	13 (38.2)	0.248

Values are presented as mean (range) or number (%).

Table 4. Operative outcomes according to tumor size

Variable	≤3 cm			>3 cm		
	Robotic (n = 26)	Laparoscopic (n = 28)	P-value	Robotic (n = 19)	Laparoscopic (n = 20)	P-value
Body mass index (kg/m^2)	27.5 (19.6–38.8)	26.2 (17.4–32.5)	0.318	25.7 (20.1–31.2)	27.4 (18.6–48.6)	0.403
Tumor location			0.439			0.152
Right	9 (34.6)	7 (25.0)		11 (57.9)	7 (35.0)	
Left	17 (65.4)	21 (75.0)		8 (42.1)	13 (65.0)	
Operative time (min)	105.5 (71–150)	92.5 (53–175)	0.072	93.8 (63–139)	114.9 (59–217)	0.032
Postoperative hospital stay (day)	3.7 (2–7)	3.9 (2–6)	0.711	3.5 (2–5)	4.1 (2–6)	0.056
Intraoperative bleeding	6 (23.1)	6 (21.4)	0.884	5 (26.3)	12 (60.0)	0.034

Values are presented as mean (range) or number (%).

0.034).

The findings suggest no significant differences in the clinical and pathological characteristics of patients undergoing robotic adrenalectomy compared to those undergoing laparoscopic adrenalectomy and that the surgical outcomes of both techniques are similar. Therefore, both approaches appear to be equally effective in treating adrenal tumors, and robotic surgery may offer some advantages.

DISCUSSION

Adrenal surgery has a long progressive history. Until 1992, open surgery was the only available surgical option [5]. However, compared with conventional open surgery, minimally invasive surgery (MIS) has many advantages. Not only is it cosmetically superior, but it also results in less postoperative pain, shorter hospital stays, and favorable oncologic outcomes in surgical oncology [6-8]. MIS is usually performed using a laparoscopic approach and was first used for laparoscopic adrenalectomy in Japan in early 1992 [9-11]. Laparoscopic adrenalectomy has become the standard approach for most adrenal tumors, owing to its successful implementation. However, this approach has several disadvantages, such as limited maneuverability of the instruments and a 2-dimensional screen. These factors make laparoscopic adrenalectomy challenging, requiring a steep learning curve [12].

As the MIS departments have become more familiar with robotic platforms, discussions are ongoing regarding the safety and efficacy of robotic adrenalectomies. The development of robotic surgical systems has led to the establishment of MIS using robotic approaches, and numerous clinical studies have been conducted [13]. The first robot-assisted adrenal gland surgery was reported in 1999 [14], followed by robotic adrenalectomies in 2001 [15]. Currently, robotic adrenalectomy is performed using various approaches at many centers worldwide, and the results have been reported in the literature [16-29]. Robotic surgery offers several advantages over pure laparoscopic surgery, including three-dimensional magnified vision, elimination of surgeon's tremors, and reduction of surgeon fatigue during the operation [30]. These advantages are particularly important for optimizing surgery in patients with large tumors and/or obesity [3,4].

In the present study, a glove port was specifically used in robotic adrenalectomy to reduce the need for additional trocar insertion and incisions when additional instruments were required. In laparoscopic adrenalectomy, the new trocar insertion is relatively easy compared to the existing one when additional instruments are needed. However, instrument insertion is not as easy in robotic surgery as in laparoscopic surgery. By using the glove port, this inconvenience is reduced, allowing for the easy insertion and removal of additional instruments without the need for new port insertion. Therefore, there was no significant difference in the operating hours between the 2 groups.

Although there was minor difference between the 2 groups overall, a significant difference was observed in the subgroup analysis that considered the tumor size. In tumors of >3 cm, both the operation time and the degree of intraoperative bleeding were significantly lower in the robotic group compared to the laparoscopic group. The robot system provides the operator with a clear and accurate view by offering a stable screen that does not shake and a 3D augmented view that the operator can directly control to obtain the desired perspective. Moreover, EndoWrist technology in the robot arm allows for more precise and free movement than the laparoscopic device. This advantage of robotic-assisted surgery was particularly noticeable when the tumor was on the right side, as large tumors often grow posteriorly to the inferior vena cava. In laparoscopic surgery, removing the tumor behind the inferior vena cava was challenging due to the restricted angulation of the laparoscopic devices. It was also difficult to properly ligate and dissect the adrenal vein. The angulation of the robotic arm made it possible to address these difficulties, making robotic adrenalectomy more effective than laparoscopic adrenalectomy for removing tumors without complications.

When the coefficients of variation for the surgical time were analyzed in both groups, the robotic surgery group showed a slightly lower variation than that in the laparoscopic surgery group. This could be attributed to the advantages of robotic surgery, which allows for more precise and controlled movements of surgical instruments, resulting in less deviation compared to laparoscopic surgery. Although robotic surgery requires more docking time than laparoscopic surgery, these results are encouraging and suggest that robotic adrenalectomy may have potential benefits over conventional laparoscopic surgery. Therefore, robotic surgery may be a better option for patients with adrenal tumors sized >3 cm.

The present study has several limitations that need to be acknowledged. Retrospective studies are prone to selection biases, confounding factors, and measurement errors, which may limit their internal validity. In addition, the lack of randomization in assigning patients to treatment groups may have introduced bias and limited the generalizability of the results. The fact that the study was conducted by a single surgeon limits the external validity of the findings. Furthermore, the arbitrary subdivision of patients based on a median pathologic tumor size of 3 cm may not be clinically meaningful and may have introduced bias into the analysis. The lack of information on patient satisfaction, postoperative pain, and cost is also a limitation of this study, as these are important outcome variables that can affect patient outcomes and quality of life. Finally, the lack of long-term follow-up, including oncological results, is a significant limitation, as it precludes any conclusions regarding the long-term safety and efficacy of robotic adrenalectomy.

In conclusion, this study provides preliminary evidence that robotic adrenalectomy may be a safe and effective alternative to laparoscopic adrenalectomy in patients with adrenal tumors sized >3 cm. However, owing to the limitations of this study, further research is needed to confirm these results and to determine the generalizability of the findings to other populations and settings.

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Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Investigation: YWC, SYK, WBJ
Writing – Original Draft: YWC, SYK
Writing – Review & Editing: YWC

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