[43]. Surgeons performing LLR were typically in their 40s. In North America and Europe, LLR was mostly performed at academic medical centers and has undergone global diffusion after the 1st ICCLLR in 2008 [12]. Meanwhile, in Japan, the majority of surgeons performing LLR belonged to middle-tier regional hospitals, where LLR has been increasingly used since its implementation in 2009 or later, comprising up to 40% of all liver resections. The Japanese social insurance system approved LLR including partial hepatectomy and left lateral sectionectomy in April 2010. In the current study, we collected data from 1,331 patients between 2005 and 2010 from 32 institutions representative of the "Endoscopic Liver Surgery Study Group." Surgeons participating were experienced in both liver surgery and laparoscopic surgery. In Japan, modern chemotherapy consists of oxaliplatin or irinotecan was introduced in 2005 [9]. It has been reported that administrative databases are not designed to resolve a specific scientific question and important true confounders may not be systematically recorded [36]. Therefore, we recently developed a unified database for CRLM produced by the Japanese Society of Hepato-Biliary Pancreatic Surgery and the Japanese Society of Cancer of the Colon and Rectum. We have access not only to the contents of operative data and accurate outcomes but also to information on perioperative non-surgical therapy, including chemotherapy, radiotherapy, or ablation therapy. This database can be applied also to those situations where the patients wish to change hospitals or change the treatment concept according to a personal anonymized number. We believe that this study reveals precise results on the emerging use of LLR for CRLM in Japan.

Laparoscopic liver resection may theoretically be superior to OLR in terms of good visibility of the operative field because of the magnifying effect and reduced blood loss from the hepatic vein due to pneumoperitoneum pressure [44]. On the other hand, some weak points remain, including the lack of sensation, limitation of the two-dimensional field of view and the difficulty to use long forceps or intraoperative ultrasonography. For several reasons (ethical, learning curve, lack of standardized techniques, benefits of laparoscopy across the field of surgery, etc.), its oncological value has not yet been determined by RCT [37]. Another major hurdle to designing a RCT is that patients may not be willing to be randomized into the OLR group [31]. As far as we know, two RCTs are in progress comparing LLR and OLR; the ORANGE II PLUS trial (http://clinicaltrials.gov/ct2/show/record/NCT01441856) and the OSLO CoMet study (http://clinicaltrials.gov/ct2/show/NCT01516710) [14]. The latter is the RCT comparing LLR and OLR for CRLM, but data are not available yet.

To date, numerous retrospective, comparative studies and meta-analyses of non-RCTs have been published [15–30]. These papers tend to demonstrate longer operative time, lower estimated blood loss, and a shorter hospital stay in LLR patients compared with OLR patients. In comparison with synchronous hepatectomy and colectomy, the laparoscopic approach was associated with shorter hospitalization durations than the open approach [29]. Overall morbidity and mortality were comparable. The LLR did not affect RFS and OS for CRLM; however, one study showed better OS for LLR patients [30]. However, comparison of surgical outcomes between LLR and OLR using all patients enrolled could be considered quite unfair, because there is serious selection bias in preoperative background factors. In the current study, after PSM matching, almost all collaborates were turned to within the range of standardized difference almost 10% differences. Recently, it was reported that there is no statistically significant difference in treatment effect between non-randomized studies with appropriate PSM analysis and RCT [37]. The PSM design might be considered the best level of evidence available, especially if based on a prospectively maintained database and carried out with an intention-to-treat analysis [32].

To date, three documents have been published using PSM, confirming short-term advantages and comparable survival outcomes in LLR patients compared with OLR patients for CRLM [31–33] (Table 3). Common short-term advantages by LLR included reduced blood loss and a shorter hospital stay. One study demonstrated lower morbidity [31] and another study showed longer operating time in LLR [33]. However, in these studies, the number of CRLM patients

Table 3 Outcomes in colorectal liver metastases (CRLM) patients who underwent laparoscopic liver resection (LLR) and open liver resection (OLR) in the papers using propensity score matching

Reference number	Patients' number LLR/OLR	Operation time	Blood loss	Morbidity	Mortality	Hospital stay	RFS/DFS	OS/DSS
[31]	35 / 140	Equal	LLR lesser	LLR lesser	Equal	LLR shorter	Equal (DFS)	Equal (OS)
[32]	52 / 52	Equal	LLR lesser	Equal	Equal	LLR shorter	Equal (DFS)	Equal (OS)
[33]	36 / 36	LLR longer	LLR lesser	Equal	Equal	LLR shorter	Equal (DFS)	Equal (OS)
This paper	171 / 342	Equal	LLR lesser	Equal	Equal	LLR shorter	Equal (RFS)	Equal (OS) (DSS)

DFS disease-free survival, *DSS* disease-specific survival, *LLR* laparoscopic liver resection, *OLR* open liver resection, *OS* overall survival, *RFS* recurrence-free survival undergoing LLR was small (35 to 52 patients), and several heterogeneous background factors existed. In the current study, the number of PSM-patients with CRLM undergoing LLR was 171, and the majority of background factors were matched. PSM matching was performed for the patients in the same period (2005 to 2011), and the survival data were calculated more than 3 years after hepatic resection. We clearly demonstrated lower intraoperative blood loss (163 g vs 415 g, $P < 0.001$) and a smaller ratio of massive bleeding larger than 1,000 mL (6.4% vs 17.6%, $P < 0.001$). It is essential for CRLM patients undergoing hepatectomy to minimize blood loss. We have reported that substantial intraoperative blood loss can worsen OS for liver cancer patients after hepatectomy [45]. The CO2 pneumoperitoneum is generally established at 10–14 mmHg, and this provides a fairly good control of back-bleeding during liver transection. Low central venous pressure (<5 mm Hg) should be used during LLR, as in open surgery [14]. Among other perioperative findings, we observed a shorter hospital stay (12 days vs 14 days, $P < 0.001$) and equivalent operation time, complication rate, transfusion rate, and R0 operation rate in LLR compared with OLR. Furthermore long-term RFS, OS, and DSS were comparable, and these results add support to previous reports.

Laparoscopic liver resection has been widely used for the treatment of malignant liver tumors instead of OLR [24]. Although we can assess the malignancy of CRLM using tumor size, tumor number, and the levels of serum tumor markers, it is difficult to evaluate the complexity of hepatic resection. Han and coworkers [13] demonstrated difficult tumor locations for LLR, and therefore we assessed this item in the present study. Practically, this variable was significantly different in the two groups, equaling however after PSM. In fact, the median operative time and the amount of intraoperative bleeding were significantly greater in the posterosuperior group than in the anterolateral group (data not shown). We have already identified important factors related to the complexity of hepatic resection, namely deep location and vascular proximity [46], but unfortunately data on these factors were not included in the current database. Lately, a novel difficulty scoring system for LLR was introduced [47]. This scoring system can be used to predict the difficulty of LLR from preoperative factors and to properly select patients according to the skill level of the surgeon.

Although OLR has been the golden standard procedure for CRLM, LLR has not proved to be a comparable surgical intervention. Specific concerns about the oncologic adequacy of laparoscopy in general include port site metastases, the trophic effect of pneumoperitoneum on malignant cells, and the inability to inspect the peritoneal cavity adequately when inspecting the liver [31, 48–51]. Therefore, we analyzed details of complications and postoperative recurrence. Morbidity rates and levels of complication were similar including no port site recurrences or seeding of malignant cells. We observed no specific disadvantages regarding recurrence in LLR patients when we analyzed recurrence-free time from initial hepatic resection, and the number and size of initial recurrences. LLR included the Pure, HALS, and the Hybrid technique [12]. The independent role of these three approaches is not well known. A recent literature review demonstrated that there is insufficient evidence to conclude that any single approach is superior to the others, although HALS and the Hybrid technique are useful when dealing with difficulties associated with Pure LLR. Conversely, the need for these two methods, which can function as a bridge to Pure LLR, may be overcome with appropriate training [47, 52].

A problematic limitation was that this study was not an RCT. Although a well-designed PSM analysis was reported to be as accurate as an RCT [36], probable minimal confounding factors could have affected the results. Second, this study was investigated in the initial period of LLR usage for CRLM in Japan. The LLR to OLR ratio was 1: 5.3. The ratio of the Pure, HALS, and Hybrid approaches were 62%: 9%: 29%. The percent increase in LLR, was 16.9% between the first half and second half. The results might be modified with an increased number of LLR. Finally, in the propensity-matched cohort, median observation periods were different between the two procedures (LLR, 41.7 months vs OLR, 49.1 months). The sample size decreased after PSM, which could have affected the accuracy of recurrence and survival-estimated data. A total of 1,121 OLR patients were reduced to 513 patients after the PSM, which is caused by the small sample size of LLR group. One fifth of the LLR patients were excluded from the final analysis that might account for PSM selection bias. We can conclude from this PSM study that LLR can provide excellent perioperative benefits without compromising oncologic outcomes or long-term survival for patients with relatively early stage of CRLM. LLR should be considered to be a standard practice for selected patients with CRLM.

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Conflict of interest Masafumi Nakamura has received lecture fees from Johnson & Johnson.

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Supporting information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Table S1 Comparison of continuous background factors for LLR and OLR before and after PSM matching.

Fig. S1 Standardized differences before and after PSM. Open circle, before propensity matching; closed triangle, after propensity matching.

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ORIGINAL ARTICLE

Multicenter comparative study of laparoscopic and open distal pancreatectomy using propensity score-matching

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Abstract

Background Laparoscopic distal pancreatectomy has been shown to be associated with favorable postoperative outcomes using meta-analysis. However, there have been no randomized controlled studies yet. This study aimed to compare laparoscopic and open distal pancreatectomy using propensity score-matching.

Methods We retrospectively collected perioperative data of 2,266 patients who underwent distal pancreatectomy in 69 institutes from 2006–2013 in Japan. Among them, 2,010 patients were enrolled in this study and divided into two groups, laparoscopic distal pancreatectomy and open distal pancreatectomy. Perioperative outcomes were compared between the groups using unmatched and propensity matched analysis.

Results After propensity score-matching, laparoscopic distal pancreatectomy was associated with favorable perioperative outcomes compared with open distal pancreatectomy, including higher rate of preservation of spleen and splenic vessels ($P < 0.001$); lower rates of intraoperative transfusion ($P = 0.020$), clinical grade of pancreatic fistula (International Study Group on Pancreatic Fistula grade B and C; $P < 0.001$), and morbidity ($P < 0.001$); and shorter hospital stay ($P = 0.001$), but a longer operative time ($P < 0.001$).

Conclusions Laparoscopic distal pancreatectomy was associated with more favorable perioperative outcomes than open distal pancreatectomy.

Keywords Laparoscopic distal pancreatectomy · Morbidity · Pancreatic fistula · Propensity score-matching

Introduction

Laparoscopic distal pancreatectomy (LDP) was first reported in 1996 by Gagner and Cuschieri [1, 2] and has since become common as a treatment method for benign pancreatic tumors due to the development of relevant surgical instruments and techniques. As LDP began to be widely performed, many retrospective studies and systematic reviews showed that LDP was not inferior to open distal pancreatectomy (ODP) in terms of short-term postoperative outcomes and that LDP was associated with a shorter hospital stay compared with ODP [3–6]. Furthermore, some systematic reviews with meta-analysis showed that LDP is associated with better short-term postoperative outcomes in terms of postoperative pain, recovery time, length of hospital stay, rate of postoperative pancreatic fistula (POPF), and postoperative morbidity [3, 5–8]. However, these systematic reviews using meta-analysis did not include any randomized controlled trials (RCTs), and thus, selection bias in treatment methods may have influenced their results [3, 5, 8–10].

Because LDP is safe and associated with favorable postoperative outcomes as described above, LDP is now a common technique for benign tumors [11]. Therefore, a RCT comparing LDP to ODP is challenging today. We organized a nationwide retrospective collection of perioperative data from patients who underwent LDP or ODP for benign tumors. Instead of a RCT, the pooled data were subjected to propensity score-matching (PSM) for comparing the outcomes of LDP and ODP [12]. The aim of this study was to establish evidence concerning postoperative outcomes after LDP for benign tumors.

Methods

Study selection

We conducted a retrospective cohort study as a project of the Japanese Society of Hepato-Biliary-Pancreatic Surgery (JHBPS) and collected perioperative data for 2,266 patients who underwent distal pancreatectomy from 2006–2013 at 69 institutes that participated in JHBPS and the Japanese Society for Endoscopic Pancreatic Surgery. The inclusion criterion was a preoperative diagnosis of a benign or low-grade malignant tumor of the pancreas, and thus, patients with preoperative diagnosis of an invasive pancreatic cancer were excluded from this study. Data were treated based on intention-to-treat concerning diagnosis and surgical method. According to the criteria, 145 patients with preoperative diagnosis as an invasive cancer, and a patient with insufficient data, were excluded from our study. Eventually, 2,120 patients were enrolled. The numbers of patients who underwent the different surgical procedures were as follows: ODP ($n = 1{,}108$), pure LDP (P-LDP; $n = 770$), hand-assisted LDP (HA-LDP; $n = 132$), and hybrid-distal pancreatectomy (HDP; $n = 110$). HDP patients were excluded from the analysis, because its definition is vague. The remaining 2,010 patients were divided into two groups, ODP ($n = 1{,}108$) and LDP ($n = 902$).

Pancreatic fistula and postoperative morbidity

Postoperative pancreatic fistula was diagnosed by the International Study Group of Pancreatic Fistula (ISGPF) and evaluated according to the following criteria: persistent drainage (>3 weeks), signs of infection, readmission within 1 month, or fluid collection with elevated drain amylase levels (>3 times the upper limit of normal serum amylase level), as previously described [13]. The definition of postoperative morbidity was a postoperative event of grade III–V of Clavien–Dindo classification or POPF of grade B or C [14, 15].

Statistical analysis

To determine the efficacy of treatment and to reduce the effect of selection bias, propensity score analysis was performed using the following algorithm. Possible confounders were chosen for their potential association with the outcome based on clinical knowledge. A propensity score was estimated using a logistic regression model using the following 14 relevant variables: age, gender, body mass index (BMI), maximum tumor size, locations of tumors, prior abdominal surgery, comorbidity, hemoglobin, albumin, carcinoembryonic antigen (CEA), carbohydrate antigen 19-9 (CA19-9), pancreatitis other than obstructive pancreatitis caused by the tumor, obstructive pancreatitis caused by the tumor, and combined resection of other organs. Propensity scores were matched using a caliper width of 0.25 multiplied by the standard deviation of values that was calculated by a logistic regression model. One patient who underwent laparoscopic surgery was matched to one patient who underwent laparotomy using a greedy nearest-neighbor matching algorithm without replacement. We used the receiver operating characteristic (ROC) and area under the curve (AUC) to measure the balance of covariates. Within this matched cohort, the AUC was 0.54 ($P = 0.009$, 95% confidence interval [CI]: 0.510–0.569) calculated from the ROC curve. Continuous variables were compared by *t*-tests, and categorical variables were compared by χ^2 test. A *P*-value < 0.05 was considered to be significant. All analyses described above were performed using SPSS software (version 22, SPSS, Chicago, IL, USA).

Results

Patient characteristics

Patient characteristics before and after PSM are shown in Table 1. Out of 902 patients in the LDP group, in 58 patients operation was converted to ODP and was counted as LDP based on intention-to-treat. In addition, 13 out of 14 factors that were important for selecting the operative method were significantly different between the LDP and ODP groups before PSM. The factors showing differences were: age, gender, BMI, tumor size, tumor location, prior abdominal surgery, comorbidity, hemoglobin, albumin, CEA, CA19-9, pancreatitis, and combined resection of other organs. Finally, 1,458 out of 2,010 enrolled patients remained, and none of the 14 factors related to patient characteristics showed a statistical difference between the LDP and ODP groups after PSM (Table 1).

Table 1 Patient characteristics

	Before PSM ($n = 2,010$)			After PSM ($n = 1,458$)		
	ODP (1,108)	LDP (902)	*P*	ODP (729)	LDP (729)	*P*
Age (years)[c]	61 ± 15	57 ± 16	<0.001*	59 ± 15	58 ± 16	0.771
Gender (male/female)	502/606	321/581	<0.001*	294/435	269/460	0.179
Body mass index (kg/m^2)[c]	22.1 ± 3.7	22.5 ± 5.1	0.038*	22.2 ± 3.7	22.4 ± 3.7	0.280
Tumor size (mm)[c]	39 ± 32	35 ± 25	0.001*	35 ± 28	35 ± 26	0.938
Tumor location Body/tail/body-tail (%)	61.1/37.2/1.7	47.6/52.3/0.1	<0.001*	54.6/44.3/1.1	53.4/46.5/0.1	0.480
Prior abdominal surgery (%)	32.5	23.4	<0.001*	27.6	26.1	0.497
Comorbidity (%)	51.9	41.4	<0.001*	45.5	45.7	0.916
Hb < 10.0 g/dL (%)	5.9	3.4	0.008*	4.6	4.0	0.607
ALB < 3.5 g/dL (%)	8.7	4.6	<0.001*	5.2	5.1	0.915
Elevated CEA (%)	11.9	8.5	0.015*	9.8	8.9	0.560
Elevated CA19-9 (%)	14.3	9.5	0.002*	8.4	10.2	0.258
Pancreatitis (%)[a]	14.0	8.0	<0.001*	9.5	8.5	0.521
Obstructive pancreatitis (%)[b]	4.3	3.4	0.181	3.3	3.6	0.733
Combined resection of other organs (%)	24.2	11.0	<0.001*	15.6	13.1	0.175

ALB albumin, *Hb* hemoglobin, *LDP* laparoscopic distal pancreatectomy, *ODP* open distal pancreatectomy, *PSM* propensity score matching. Elevated CEA and CA19-9: Increased value of carcinoembryonic antigen (CEA) and carbohydrate antigen 19-9 (CA19-9) beyond the standards of institutes

* Indicates statistical significance ($P < 0.05$)

[a] Pancreatitis except obstructive pancreatitis by tumor

[b] Obstructive pancreatitis caused by tumor

[c] Values are mean ± standard deviation

Perioperative outcomes

The matched cohort was evaluated for differences in perioperative outcomes between LDP and ODP (Tables 2 and 3), and the results are shown in Table 2 with the results of an unmatched analysis. LDP showed several favorable outcomes compared with ODP, except for operative time (319.2 and 261.4 min for LDP and ODP, respectively; $P < 0.001$). The preservation rates of the spleen (29.9% vs 13.2%; $P < 0.001$) and splenic vessels (25.7% vs 12.3%; $P < 0.001$) were higher in the LDP group than those in the ODP group. The intraoperative transfusion rate was significantly lower in LDP than in ODP (4.0% vs 6.8%; $P = 0.020$, odds ratio = 0.574 with 95% CI = 0.358–0.919). The clinical grade of pancreatic fistula (POPF-B.C) was less in the LDP group than in the ODP group (18.4% vs 28.2%; $P < 0.001$, odds ratio = 0.575 with 95% CI = 0.448–0.739). The overall morbidity rate was less for LDP than for ODP (24.0% vs 32.5%; $P < 0.001$, odds ratio = 0.654 with 95% CI = 0.520–0.824). Details of intraoperative complications and overall morbidity are shown in Table 4. LDP was associated with a shorter hospital stay compared with ODP (18.8 vs 23.2 days; $P = 0.001$). No significant differences were observed in the 30-day and 90-day mortality rates between the two groups. Although the POPF-A.B.C appeared to be different between the groups, with PSM no statistical difference was observed.

Discussion

Although no RCT comparing LDP with ODP has been published, LDP rapidly has become a common treatment for benign tumors [11]. Our study included the largest number of patients in a comparative study of LDP with ODP out of all studies that we could find on PubMed [16]. The groups matched by propensity scores were compared for postoperative factors. LDP showed several favorable results, such as less blood loss; lower rates of transfusion, POPF-B.C, and overall morbidity; and shorter hospital stay. Odds ratios of LDP to ODP for transfusion, POPF-B,C, and morbidity were 0.574, 0.575, and 0.654, respectively. Our observation that LDP showed favorable short-term outcomes may accelerate the spread of LDP.

When we compared patient characteristics between the LDP and ODP groups, 13 out of 14 factors related to patient characteristics showed significant differences before PSM. As expected, patients who underwent LDP tended to be healthy young women, and operations were expected to be simple without prior operation or pancreatitis as shown in Table 1.

Most of the systematic reviews and independent comparative studies have coincided with each other regarding the non-inferiority of LDP in terms of postoperative outcomes and the superiority of LDP with respect to hospital stay and transfusion rate [3, 5, 7, 8]. However, there is controversy about

Table 2 Perioperative outcomes

	Before PSM ($n = 2{,}010$)			After PSM ($n = 1{,}458$)		
	ODP (1,108)	LDP (902)	*P*	ODP (729)	LDP (729)	*P*
Operative time (min)§	268 ± 115	316 ± 127	<0.001*	261 ± 119	319 ± 129	<0.001*
Estimated blood loss (g)	568 ± 806	243 ± 388	<0.001*	499 ± 740	254 ± 384	<0.001*
Drain amylase (IU/L)§	8066 ± 15983	8085 ± 13783	0.979	9324 ± 17591	8084 ± 14662	0.181
Days of drainage§	14.6 ± 18.1	12.5 ± 34.4	0.086	15.7 ± 19.3	12.6 ± 37.7	0.052
Day of meal intake§	5.6 ± 5.2	5.5 ± 6.1	0.483	5.6 ± 5.1	5.3 ± 5.8	0.392
Hospital stay (days)§	23.3 ± 17.7	18.9 ± 14.4	<0.001*	23.2 ± 18.8	18.8 ± 14.7	0.001*
Preservation of spleen (%)	10.6	32	<0.001*	13.2	29.9	<0.001*
Preservation of splenic vessels (%)	9.7	27.5	<0.001*	12.3	25.7	<0.001*
Intraoperative transfusion (%)	10.0	3.9	<0.001*	6.8	4.0	0.020*
Intraoperative complication (%)	5.1	4.1	0.29	4.0	4.7	0.527
POPF-A.B.C (%)	59.7	66.2	0.003*	64.0	65.8	0.489
POPF-B.C (%)	26.7	18.2	<0.001*	28.2	18.4	<0.001*
Overall morbidity (%)	31.6	23.6	<0.001*	32.5	24.0	<0.001*
30-day mortality (yes/no)	2/1106	1/901	0.577	0/729	1/728	0.500
90-day mortality (yes/no)	3/1105	2/900	0.596	1/728	2/727	0.500

LDP laparoscopic distal pancreatectomy, *ODP* open distal pancreatectomy, *POD* postoperative day, *POPF-A.B.C* postoperative pancreatic fistula of grade A, B and C, *POPF-B.C* postoperative pancreatic fistula of grade B and C, *PSM* propensity score matching.
* Indicates statistical significance ($P < 0.05$).
§ Values are mean ± standard deviation, drain amylase was measured on 1POD.

Table 3 Odds ratios for postoperative pancreatic fistula (POPF) and morbidity after propensity score-matching (PSM)

	Odds ratio (LDP/ODP)	95% confidence interval	*P*
Intraoperative transfusion	0.574	0.358 to 0.919	0.020*
POPF-BC	0.575	0.448 to 0.739	<0.001*
Overall morbidity	0.654	0.520 to 0.824	<0.001*

LDP laparoscopic distal pancreatectomy, *ODP* open distal pancreatectomy, *POPF-B.C* postoperative pancreatic fistula of grade B and C, *PSM* propensity score matching.
* Indicates statistical significance ($P < 0.05$).

Table 4 Details of intraoperative complications and overall morbidity

	Before PSM		After PSM	
	ODP	LDP	ODP	LDP
Intraoperative complication				
Bleeding	46	33	23	31
Injury of other organs	5	1	3	1
Miscellaneous	5	3	3	2
Postoperative morbidity*				
POPF-B.C	296	164	237	134
Intra-abdominal abscess	31	24	16	22
Delayed gastric emptying	9	5	6	5
Bleeding	5	12	4	10
Respiratory failure	5	1	2	1
Wound infection	2	3	2	2
Miscellaneous	56	30	38	21

LDP laparoscopic distal pancreatectomy, *ODP* open distal pancreatectomy, *POPF-B.C* postoperative pancreatic fistula of grade B and C, *PSM* propensity score matching.
* Some patients had more than one postoperative event.

the superiority of POPF and morbidity [3, 5, 7–10, 17]. Interestingly, we showed that LDP were associated with significantly higher POPF-A,B,C than ODP before PSM, but the difference disappeared after PSM. This meant that some of the 13 factors related to patient characteristics, which were significantly different between the LDP and ODP groups, accounted for the difference in the rate of POPF-A,B,C. Similar biases may have accounted for the difference in the rate of POPF between studies.

In our study, patients undergoing LDP showed a lower rate of POPF-B,C than patients undergoing ODP before and after PSM. There are some possible factors that may be responsible for the superiority of LDP in terms of POPF-B,C. One possible factor is the difference in methods used for transecting the pancreas. However, a previous study reported that the major transection methods for ODP and LDP, hand-sewn closure and stapling, respectively, did not cause differences in POPF and morbidity [18]. This meant that the ability to seal the pancreatic stump in LDP and ODP may be comparable. This idea was supported by our data that the drain amylase concentration on the first postoperative day was comparable between the LDP and ODP groups. Meanwhile, infection is one of the key factors for deteriorated POPF [19], and the infection risk is lower with LDP compared to ODP [3]. This could be one explanation for the decrease in POPF among patients undergoing LDP.

The operative time did not differ between the LDP and ODP groups in most of the meta-analysis, but LDP was associated with a significantly longer operative time than ODP in our study. This may be a result of the settings for matching factors. We set the rate of preservation of spleen and splenic vessels as a perioperative outcome, because we did not have data concerning the rate of intent to preserve them. It appeared that LDP had significantly higher rates for these factors. Methods with the preservation of the spleen and splenic vessels tend to require more time than methods without preservation [20–22]. Therefore, we speculated that LDP required more time because of the high rate of these preservation methods. Another reason may be the inclusion of data from institutes that were not high volume centers. Most previous reports from single centers were usually from high volume centers that were familiar with LDP, and surgeons at low volume institutes may still be in the learning curve for LDP [23, 24].

A limitation of our study is that PSM will not correct biases from unmeasured confounders. However, it is still useful to evaluate a treatment method more precise than conventional retrospective studies [12, 25].

In conclusion, LDP was associated with several favorable perioperative outcomes, particularly low rates of POPF and morbidity, in a large number of patients with PSM. However, we analyzed short-term outcomes exclusively in this study. We need to evaluate long-term prognosis after LDP even for benign and low grade malignant tumors before setting LDP as a first line method of resection for pancreatic body tumors.

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ORIGINAL ARTICLE

Effects of body mass index (BMI) on surgical outcomes: a nationwide survey using a Japanese web-based database

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Abstract
Purpose To define the effects of body mass index (BMI) on operative outcomes for both gastroenterological and cardiovascular surgery, using the National Clinical Database (NCD) of the Japanese nationwide web-based database.
Methods The subjects of this study were 288,418 patients who underwent typical surgical procedures between January 2011 and December 2012. There were eight gastroenterological procedures, including esophagectomy, distal gastrectomy, total gastrectomy, right hemicolectomy, low anterior resection, hepatectomy of >1 segment excluding the lateral segment, pancreaticoduodenectomy, and surgery for acute diffuse peritonitis ($n = 232{,}199$); and five cardiovascular procedures, including aortic valve replacement, total arch replacement (TAR), descending thoracic aorta replacement (descending TAR), and on- or off-pump coronary artery bypass grafting ($n = 56{,}219$). The relationships of BMI with operation time and operative mortality for each procedure were investigated, using the NCD.
Results Operation times were longer for patients with a higher BMI. When a BMI cut-off of 30 was used, the operation time for obese patients was significantly longer than that for non-obese patients, for all procedures except esophagectomy ($P < 0.01$). The mortality rate based on BMI revealed a U-shaped distribution, with both underweight and obese patients having high mortality rates for almost all procedures.
Conclusions This Japanese nationwide study provides solid evidence to reinforce that both obesity and excessively low weight are factors that impact operative outcomes significantly.

Keywords National clinical database · Nationwide web-based database · Body mass index · Operation time · Operative mortality

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Table 1 Summary of past studies on the effect of body mass index on surgical outcomes

Year	References	*n*	Disease	Operation	BMI cut-off values	Operation time (min) *P* value	Mortality (%) *P* value
2013	Bhayani et al. [7]	794	–	Subtotal or total esophagectomy	18.5–25 vs. 35≤	316 vs. 308 n.s.	3.3 vs. 2.3 ns
2013	Sugimoto et al. [8]	216	Gastric cancer	Laparoscopic distal gastrectomy	25> vs. 25≤	200 vs. 212 0.005	0 vs. 0 ns
2014	Makino et al. [9]	152	Colon cancer	Laparoscopic colectomy	30> vs. 30≤	157 vs. 182 0.008	0 vs. 0 ns
2012	Saunders et al. [10]	403	–	Liver resection	18.5–24.9 vs. 40≤	306 vs. 402 ns	6 vs. 27 0.05
2014	El Nakeeb et al. [11]	471	Some	Pancreaticoduodenectomy	25> vs. 25≤	300 vs. 321 0.003	0.8 vs. 7.1 0.001
2012	Zdichavsky et al. [12]	596	Some	Laparoscopic cholecystectomy	30> vs. 30≤	73.5 vs. 87 <0.001	–
2011	Alam et al. [13]	13,115	–	Coronary artery bypass graft	30> vs. 30≤	39.3 vs. 41.7* <0.0001	3.7 vs. 2.9 ns
2012	Smith et al. [14]	1066	Aortic stenosis	Aortic valve replacement	25> vs. 25–30 vs. 30<	72.9 vs. 74.9 vs. 76.5** ns	5.6 vs. 2.8 vs. 4.5 ns

BMI body mass index

* Aortic clamp time, ** cross-clamp time

Introduction

With the proportion of obese people in world populations increasing, obesity-related illnesses have become a major concern globally [1]. The World Health Organization (WHO) has documented that 34 % of adult men and 35 % of adult women have a body mass index (BMI) of more than 25, and that 10 % of adult men and 14 % of adult women worldwide are obese (BMI $\geq$ 30) [2]. In the United States, 34.9 % of adults are obese [3]. Japan is no exception to this trend, with a National Health and Nutrition Survey (2012) conducted by the Ministry of Health, Labour and Welfare revealing that 29.1 % of adult men and 19.4 % of adult women have a BMI of more than 25. A rising BMI and a growing obese population in Japan have been reported, especially among men, as well as middle-aged and older women [4–7]. Although there have been a number of studies on the relationship between obesity and operative outcomes, their conclusions are inconsistent (Table 1) [8–15]. Moreover, many of these studies were performed at individual institutions and there have been no large-scale surveys comparing different surgical areas. Ultimately, it has not yet been established whether obesity adversely affects operative outcomes, such as the operation time and risk. Thus, we conducted a cross-sectional investigation of the effects of BMI on operation time and operative mortality for both gastroenterological and cardiovascular surgery, using a Japanese nationwide database.

Methods

The nationwide database system

In January 2011, Japan's National Clinical Database (NCD) became accessible on-line, with the cooperation of some of the nation's surgical associations. The NCD is a large-scale nationwide database, in which data from over 1,200,000 surgical cases were collected from more than 3500 hospitals in 2011. The information about operations performed nationwide was registered in the NCD by data management departments from the participating institutions. The data were evaluated annually using a web-based data management system to assure data traceability. This system also validated data consistency by randomly inspecting the participating institutions. Several clinical studies conducted by various societies have used the NCD data [16–18].

Patients

We analyzed data from a total 288,418 patients who underwent a typical procedure in the areas of gastroenterological and cardiovascular surgery between 1 January 2011 and 31 December 2012. There were 13 procedures in total: esophagectomy (Eso), distal gastrectomy (DG), total gastrectomy (TG), right hemicolectomy (RHC), low anterior resection (LAR), hepatectomy of more than one segment apart from the lateral segment (Hx), pancreaticoduodenectomy (PD), surgery for acute diffuse peritonitis (ADP), aortic valve replacement (AVR), total arch replacement (TAR), descending thoracic aorta replacement (descending TAR), coronary artery bypass graft (CABG) on-pump, and CABG off-pump. Patients who did not consent to their data being used were excluded from this analysis. Records with missing data for age, sex, or status at postoperative day (POD) 30 were also excluded, as were data related to patients with a BMI of less than 10 or over 50 as these values were obviously erroneous.

Study outcomes

The three outcomes examined using the NCD were BMI, operation time, and operative mortality. BMI is calculated as weight (in kilograms) divided by the square of height (in meters). Operative mortality included all deaths occurring within the index hospitalization period, regardless of the length of hospital stay (up to 90 days), or after hospital discharge (within 30 days after surgery). We evaluated influences of stratified BMI on operation time and operative mortality.

Statistical analyses

All statistical analyses were conducted using SPSS (version 20). We performed univariate comparisons of BMI and operation time, using the unpaired Student's t test and Chi-square test. A P value of 0.05 was considered significant.

Results

Table 2 summarizes the backgrounds of each procedure. There were 232,199 patients undergoing 1 or more of 8 gastroenterological surgery procedures and 56,219 patients undergoing 1 or more of 5 cardiovascular surgery procedures.

Table 2 Background parameters

Operation	Number	Sex (male/female)	Age (mean ± SD)
Eso	10,825	9124/1701	66.1 ± 9.3
DG	63,650	42,438/21,212	69.1 ± 11.5
TG	37,817	27,877/9940	69.0 ± 11.0
RHC	37,750	18,878/18,872	71.7 ± 12.1
LAR	33,217	21,436/11781	66.2 ± 11.6
Hx	14,903	10,456/4447	67.0 ± 11.5
PD	17,485	10,841/6644	68.5 ± 10.2
ADP	16,552	10,020/6532	64.9 ± 18.6
AVR	14,827	7914/6913	72.4 ± 10.7
TAR	10,594	7421/3173	69.5 ± 11.6
Descending TAR	5605	4129/1476	69.6 ± 12.3
CABG on-pump	9221	7232/1989	67.7 ± 9.9
CABG off-pump	15,972	12,547/3425	69.1 ± 9.7

Eso esophagectomy, *DG* distal gastrectomy, *TG* total gastrectomy, *RHC* right hemicolectomy, *LAR* low anterior resection, *Hx* hepatectomy performed for >1 segment except for the lateral segment, *PD* pancreaticoduodenectomy, *ADP* surgery for acute diffuse peritonitis, *AVR* aortic valve replacement, *TAR* total arch replacement, *CABG* coronary artery bypass graft

BMI distribution

Figure 1 shows the BMI distribution of all the patients whose data were analyzed. Approximately 60 % of the procedures (61.2–69.9 %) were performed on patients with a normal physique, with a BMI of 18.5–25. Of the remaining patients, 2.6 % were obese, 20.3 % were overweight, and 13.4 % were underweight. There were differences in BMI distributions between patients undergoing gastroenterological and cardiovascular procedures. The largest category of patients undergoing gastroenterological surgery had a BMI of 18.5–22, and the largest category of those undergoing cardiovascular surgery had a BMI of 22–25. The proportion of overweight patients (with a BMI of 25–30) among those undergoing gastroenterological surgery was less than 20 %, whereas the proportion of overweight patients among those undergoing cardiovascular surgery was more than 20 %. The proportion of obese patients did not exceed 3 % in any of the gastroenterological surgery groups, but it exceeded 4 % in all of the cardiovascular surgery groups, being especially low in the Eso (1 %) group and especially high in the on-pump (5 %) and off-pump (4.6 %) CABG groups. The proportion of underweight patients (with a BMI of <18.5) among those undergoing gastroenterological surgery, apart from Hx, was at least 10 %, whereas among those undergoing cardiovascular surgery, apart from AVR, it was no more than 10 %. This rate was high for ADP (23.3 %), Eso (21.1 %), and PD (14.9 %), but low for off-pump (5 %) and on-pump (5.1 %) CABG.

Operation time by BMI

Figure 2 shows the operation times for all procedures, which became longer as the BMI rose. When a BMI cutoff of 30 was used, the operation time for obese patients was significantly longer than that for those who were not obese, for all procedures except Eso (Table 3). Among the gastroenterological operations, the operation time for obese patients was prolonged for PD (56 ± 8.3 min, mean ± SE), TG (50 ± 4.0 min), and LAR (50 ± 3.9 min), while among the cardiovascular operations, the operation time for obese patients was prolonged for TAR (55 ± 8.4 min) and descending TAR (54 ± 13.8 min). The operation times were originally longer for men than for women, for all of

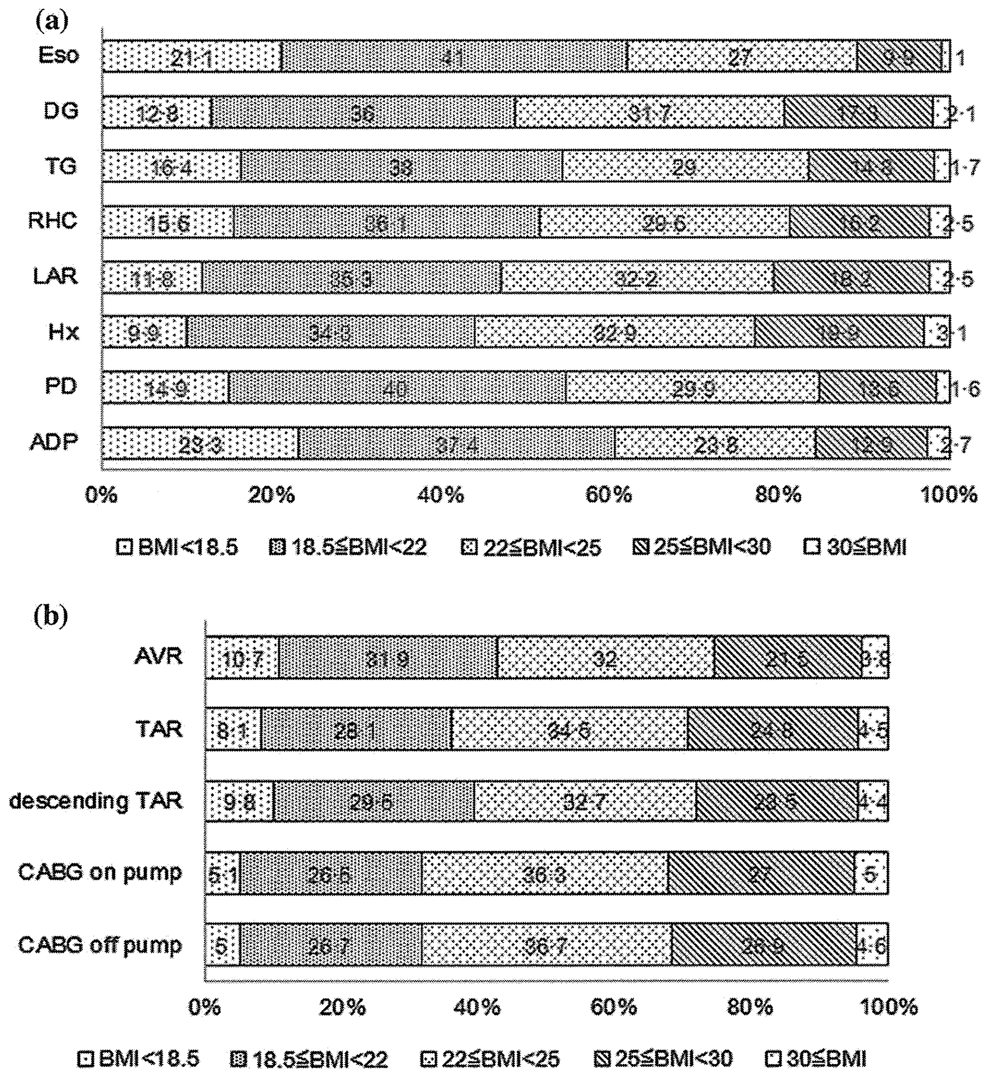


Fig. 1 **a** Body mass index (BMI) distribution in the gastroenterological surgery procedures (%). *Eso* esophagectomy, *DG* distal gastrectomy, *TG* total gastrectomy, *RHC* right hemicolectomy, *LAR* low anterior resection, *Hx* hepatectomy performed for >1 segment apart from the lateral segment, *PD* pancreaticoduodenectomy, *ADP* surgery for acute diffuse peritonitis. **b** BMI distribution in the cardiovascular surgery procedures (%). *AVR* aortic valve replacement, *TAR* total arch replacement, *CABG* coronary artery bypass graft

the procedures (Table 4). The operation time was significantly longer for obese men than for men who were not obese, and this result was consistent among all procedures. The differences in the effects of obesity on operation times between men and women varied among the procedures. The prolongation of operation time by at least 60 min because of obesity was greater in men than in women undergoing LAR, TAR, and descending TAR. Among patients undergoing Hx, the impact of obesity on operation time was greater for women than for men.

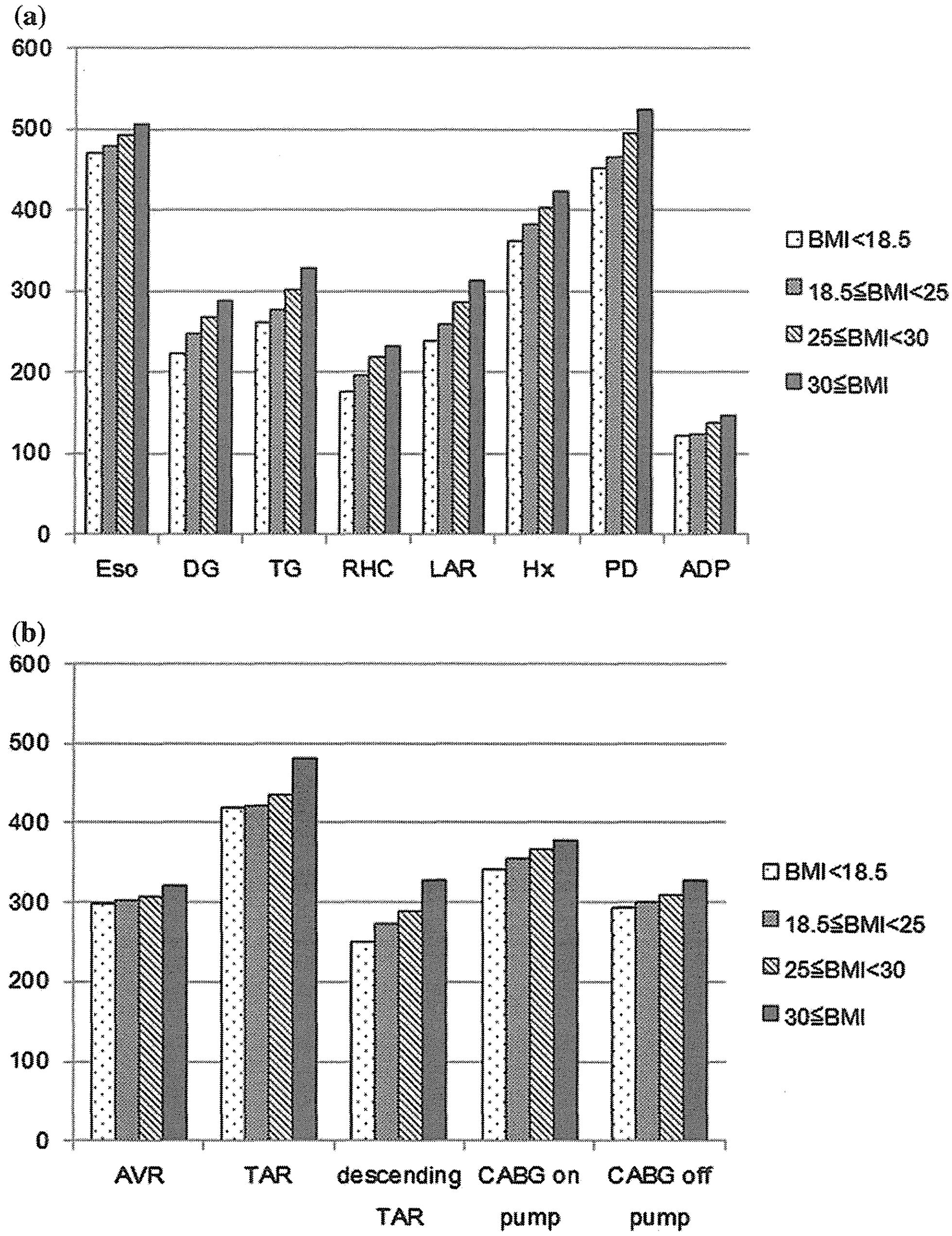
Influence of BMI on operative mortality

Figure 3 shows the operative mortality rates. The mortality rate according to BMI had a U-shaped distribution for most procedures, with both underweight and obese patients having higher mortality rates. Overweight patients tended to have the lowest mortality risk among those undergoing cardiovascular surgery, but not among those undergoing gastroenterological surgery. Obesity tended to have a small effect on mortality among patients undergoing Eso or DG. Among patients undergoing PD, those who were underweight had the lowest mortality rate.

Discussion

We conducted a large-scale trans-disciplinary study on the effects of BMI on gastroenterological vs. cardiovascular surgery, using NCD accumulated in Japan. Several previous studies have demonstrated a cause-and-effect relationship between BMI and operative outcomes, including operation time and operative mortality in various fields, including gastroenterological procedures for esophageal

Fig. 2 **a** Operation times for the gastroenterological surgery procedures (min). *Eso* esophagectomy, *DG* distal gastrectomy, *TG* total gastrectomy, *RHC* right hemicolectomy, *LAR* low anterior resection, *Hx* hepatectomy performed for >1 segment, apart from the lateral segment, *PD* pancreaticoduodenectomy, *ADP* surgery for acute diffuse peritonitis. **b** Operation times for the cardiovascular surgery procedures (min). *AVR* aortic valve replacement, *TAR* total arch replacement, *CABG* coronary artery bypass graft



cancer [8], gastric cancer [9], colon cancer [10], liver cancer [11], pancreatic cancer [12], and laparoscopic cholecystectomy [13], as well as cardiac procedures, including CABG and valve replacement [14, 15]. However, according to the literature, the influences of BMI on surgery vary among operative procedures and even for the same procedure, so the effects of BMI on operative outcomes remain controversial. To date, two studies involving a large number of cases have been reported. In a study of 30,765 patients undergoing surgery for gastric cancer or colorectal cancer in Japan, Yasanuga et al. found that obese patients had significantly higher rates of postoperative complications and that underweight patients had significantly higher rates of both postoperative complications and operative mortality than those with a normal BMI [19]. In a study of 13,115 patients undergoing CABG, Alam et al. found that obese patients had significantly prolonged total circulatory bypass and aortic clamp times, as well as an increased risk of postoperative respiratory failure, postoperative renal failure, and surgical site infections, but not of operative mortality [14]. The number of patients in the present study was greater than that in either of the previous studies and we also examined data for various procedures in two major fields. We confirmed that BMI has similar effects on nearly all procedures in the fields of gastroenterological and cardiovascular surgery in this nationwide survey.

Table 3 Operation times (min) according to a body mass index cut-off value of 30

Operation	Total number	Operation time (min)		Prolongation (min)	*P* value
	(BMI < 30:30 ≤ BMI)	BMI < 30	30 ≤ BMI		
Eso	10,825 (10,727:98)	479	505	26	ns
DG	63,650 (62,391:1259)	248	288	40	<0.001
TG	37,817 (37,215:602)	279	329	50	<0.001
RHC	37,750 (36,850:900)	197	233	36	<0.001
LAR	33,217 (32,409:808)	262	312	50	<0.001
Hx	14,903 (14,459:444)	384	424	40	<0.001
PD	17,485 (17,229:256)	468	524	56	<0.001
ADP	16,552 (16,117:435)	127	148	21	<0.001
AVR	14,827 (14,257:570)	304	321	17	<0.001
TAR	10,594 (10,114:480)	426	481	55	<0.001
Descending TAR	5605 (5356:249)	274	328	54	<0.001
CABG on-pump	9221 (8760:461)	358	379	21	<0.001
CABG off-pump	15,972 (15,238:734)	303	328	25	<0.001

Student's *t* test was used to compare the mean operation time between obese (BMI ≥ 30) and non-obese (BMI < 30) patients. Statistical significance was set at $P < 0.05$

Eso esophagectomy, *DG* distal gastrectomy, *TG* total gastrectomy, *RHC* right hemicolectomy, *LAR* low anterior resection, *Hx* hepatectomy performed for >1 segment apart from the lateral segment, *PD* pancreaticoduodenectomy, *ADP* surgery for acute diffuse peritonitis, *AVR* aortic valve replacement, *TAR* total arch replacement, *CABG* coronary artery bypass graft, *BMI* body mass index

Operation times were longer for patients with a higher BMI. When a BMI cut-off of 30 was used, the operation time was significantly longer for obese patients for all procedures except Eso. The procedure associated with the greatest prolongation of operation time was PD, by 56 min, while AVR was prolonged by at least 17 min. The results of the previous studies were conflicting about the influences of obesity on operation time, but those of the present study allowed us to conclude that obesity prolongs the operation time for nearly all the procedures studied. Interestingly, for all procedures, the operation times were longer for men than for women, and they were significantly longer for men who were obese than men who were not. We also noted differences among procedures in the prolongation of operation time due to obesity between men and women. It is noteworthy that men typically have a body type characterized by visceral fat accumulation, whereas women tend to show subcutaneous fat accumulation. These body type differences may account for the differences in operative times and the prolongation of surgery because of obesity.

The mortality rates according to BMI showed a U-shaped distribution, with both underweight and obese patients having high mortality rates, except when PD was the procedure performed. Prior reports from Western countries showed similar mortality curves. These studies demonstrated the so-called 'obesity paradox' in that obesity exerts an advantageous effect on morbidity and mortality, compared with normal BMI, in surgical patients [20–22]. Davenport et al. [22] reported that patients with mild obesity, defined as a BMI over 30 but under 35, had a lower 30-day mortality rate than patients of normal weight following vascular surgery. The BMI category with the lowest mortality risk is lower in Asians than in Western populations because Asians have a higher percentage of body fat than Westerners at the same BMI [3, 23]. Deurenberg et al. [24] reported the BMI values of East Asians to be lower, by 1.9–3.2 %, than in Western people when the percentage of body fat was the same. The adverse effect of obesity on short-term prognosis in patients undergoing surgery for a malignant disease would be due to not only the high technical difficulty of the necessary surgical procedures in the obese patient, but to BMI-dependent differences in the severity of the cancer. However, the influence of BMI on malignancy remains controversial [25, 26]. Mullen et al. [27] reported that underweight patients had a significantly higher postoperative death rate, with an odds ratio (OR) of 5.24 and a 95 % confidence interval (CI) of 1.7–16.2, after major surgery for gastrointestinal cancer. As in previous studies, the underweight patients in the present series had higher mortality, which we speculate is related to a reduced capacity to tolerate surgery because of their underlying nutritional deficiencies and probable advanced stages of gastroenterological cancer.

This study has the advantages of being nationwide and including a very large number of cases; however, there are limitations because of its retrospective nature and cross-sectional design. Moreover, certain details were not

Table 4 Operation times (min) according to a body mass index cut-off value of 30 and gender

Operation	Gender	Total number	Operation time (min)		Prolongation (min)	P value
		(BMI < 30:30 ≤ BMI)	BMI < 30	30 ≤ BMI		
Eso	Male	9124 (9036:88)	488	521	33	<0.05
	Female	1701 (1691:10)	432	363	−69	ns
DG	Male	42438 (41674:764)	255	303	48	<0.001
	Female	21212 (20717:495)	234	265	31	<0.001
TG	Male	27877 (27484:393)	284	338	54	<0.001
	Female	9940 (9731:209)	264	313	49	<0.001
RHC	Male	18878 (18505:373)	206	251	45	<0.001
	Female	18872 (18345:527)	187	221	34	<0.001
LAR	Male	21,436 (21,013:423)	269	334	65	<0.001
	Female	11,781 (11,396:385)	248	287	39	<0.001
Hx	Male	10,456 (10,162:294)	392	428	36	<0.001
	Female	4447 (4297:150)	368	417	49	<0.001
PD	Male	10,841 (10,715:126)	480	540	60	<0.001
	Female	6644 (6514:130)	448	508	60	<0.001
ADP	Male	10,020 (9790:230)	127	153	26	<0.001
	Female	6532 (6327:205)	126	142	16	<0.001
AVR	Male	7914 (7687:227)	314	354	40	<0.001
	Female	6913 (6570:343)	292	300	8	ns
TAR	Male	7421 (7075:346)	427	494	67	<0.001
	Female	3173 (3039:134)	422	450	28	<0.05
Descending TAR	Male	4129 (3945:184)	275	343	68	<0.001
	Female	1476 (1411:65)	269	286	17	ns
CABG on-pump	Male	7232 (6885:347)	360	380	20	<0.001
	Female	1989 (1875:114)	351	375	24	<0.05
CABG off-pump	Male	12,547 (12,020:527)	305	334	29	<0.001
	Female	3425 (3218:207)	293	312	19	<0.01

Student's t test was used to compare the mean operation time between obese (BMI ≥ 30) and non-obese (BMI < 30) patients by sex. Statistical significance was set at $P < 0.05$

Eso esophagectomy, *DG* distal gastrectomy, *TG* total gastrectomy, *RHC* right hemicolectomy, *LAR* low anterior resection, *Hx* hepatectomy performed for >1 segment apart from the lateral segment, *PD* pancreaticoduodenectomy, *ADP* surgery for acute diffuse peritonitis, *AVR* aortic valve replacement, *TAR* total arch replacement, *CABG* coronary artery bypass graft, *BMI* body mass index

assessed, such as the presence or absence of endoscopic surgery, emergency vs. non-urgent status, and co-existent illnesses, including hypertension and diabetes. Various factors other than BMI can affect operative outcomes, and these factors differ among operative procedures. It is important to analyze precise risks, including all relevant factors, for a broader range of operative procedures in the future. However, we should consider both obesity and very low body weight as the key factors impacting outcomes.

In the present study, a high BMI was shown to influence health economics and inflict excess burden on surgeons, considering the prolonged operation times for all surgical procedures evaluated. Yet, there are no additional fees in relation to obesity, in either Japan or, to our knowledge, any other country. Given the added burden associated with this condition, it is anticipated that the medical economics of providing surgical treatment for obese patients will be reviewed.

Conclusion

We investigated the effects of BMI on both gastroenterological and cardiovascular surgical procedures based on data from 288,418 patients, obtained from a Japanese nationwide database. The operation time was significantly longer for patients who were obese than for those who were not, for all procedures except Eso. Furthermore, both

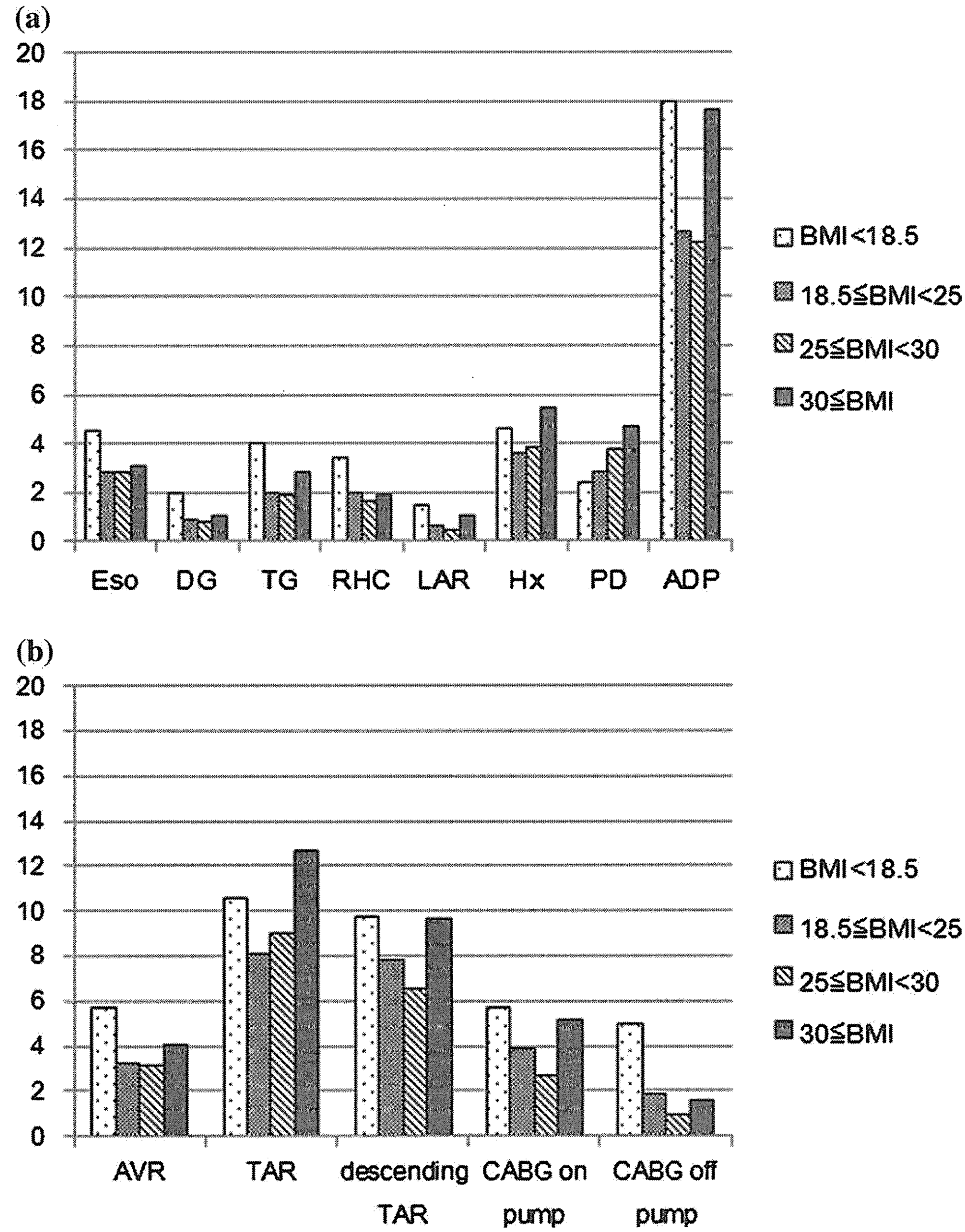


Fig. 3 **a** Operative mortality for the gastroenterological surgery procedures (%). *Eso* esophagectomy, *DG* distal gastrectomy, *TG* total gastrectomy, *RHC* right hemicolectomy, *LAR* low anterior resection, *Hx* hepatectomy performed for >1 segment except for the lateral segment, *PD* pancreaticoduodenectomy, *ADP* surgery for acute diffuse peritonitis. **b** Operative mortality for the cardiovascular surgery procedures (%). *AVR* aortic valve replacement, *TAR* total arch replacement, *CABG* coronary artery bypass graft

obese and underweight patients had high mortality rates. This Japanese nationwide study provides further evidence that obesity and very low bodyweight are both factors with significant adverse effects on operative outcomes.

Compliance with ethical standards

Conflict of interest None of the authors has any conflicts of interest to disclose.

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ORIGINAL ARTICLE

Surgical risk model for acute diffuse peritonitis based on a Japanese nationwide database: an initial report on the surgical and 30-day mortality

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Abstract

Purpose Acute diffuse peritonitis (ADP) is an important surgical complication associated with high morbidity and mortality; however, the risk factors associated with a poor outcome have remained controversial. This study aimed in collecting integrated data using a web-based national database system to build a risk model for mortality after surgery for ADP.

Methods We included cases registered in the National Clinical Database in Japan. After data cleanup, 8,482 surgical cases of ADP from 1,285 hospitals treated between January 1 and December 31, 2011 were analyzed.

Results The raw 30-day and surgical mortality rates were 9.0 and 14.1 %, respectively. The odds ratios (>2.0) for 30-day mortality were as follows: American Society of Anesthesiologists (ASA) class 3, 2.69; ASA class 4, 4.28; ASA class 5, 8.65; previous percutaneous coronary intervention (PCI), 2.05; previous surgery for peripheral vascular disease (PVD), 2.45 and disseminated cancer, 2.16. The odds ratios (>2.0) for surgical mortality were as follows: ASA class 3, 2.27; ASA class 4, 4.67; ASA class 5, 6.54, and disseminated cancer, 2.09. The C-indices of 30-day and surgical mortality were 0.851 and 0.852, respectively.

Conclusion This is the first report of risk stratification after surgery for ADP using a nationwide surgical database. This system could be useful to predict the outcome of surgery for ADP and for evaluations and benchmark performance studies.

Keywords Acute diffuse peritonitis · Risk factor · Mortality · Risk model

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Introduction

Acute diffuse peritonitis (ADP) is an important surgical complication associated with a high incidence of morbidity and mortality [1–4], and is defined as the uncontained rapid spread of an intra-abdominal infection beyond the organ of origin to multiple (2–4) quadrants of the intra-abdominal cavity, regardless of the underlying disease processes, such as a ruptured appendix, ischemic colitis, gastrointestinal (GI) tract perforation, etc. [2–5]. Emergency surgery is defined as a surgery performed on a patient immediately after the diagnosis [6]. Although a definite preoperative diagnosis of a detailed etiology is difficult even using the recently developed imaging modalities [7, 8], the surgical management of ADP involves immediate evacuation of all purulent collections and source control [1–3].

Although the mortality rate from intra-abdominal infections was close to 90 % in the early 1900s, prior to the introduction of the basic principles of surgery, in the modern era, the reduction in mortality to below 20 % has resulted due to the better understanding of the role of damage control, prevention of intra-abdominal compartment