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Efficacy of minimally invasive distal gastrectomy for elderly patients with clinical stage I/IIA gastric cancer: a propensity-score matched analysis

Makoto Hikage[1] · Keiichi Fujiya[1] · Satoshi Kamiya[1] · Yutaka Tanizawa[1] · Etsuro Bando[1] · Masanori Terashima[1]

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Abstract

Background Phase III trials have shown the non-inferiority of minimally invasive distal gastrectomy (MIDG) comparison with open distal gastrectomy (ODG) in patients with gastric cancer; however, it remains unclear whether MIDG is also effective in the elderly. This study aimed to clarify the efficacy of MIDG in elderly gastric cancer patients.

Patients and methods This study included 316 patients older than 75 years with clinical stage I/IIA gastric cancer who underwent distal gastrectomy from August 2008 to December 2016 at the Shizuoka Cancer Centre. The long-term outcomes between MIDG and ODG were compared after propensity score matching.

Results After propensity score matching, there were 97 patients each in the MIDG and ODG groups, with an improved balance of confounding factors between the two groups. MIDG was associated with significantly longer operative time and a lower level of blood loss than ODG. The incidence of complications was comparable between the two groups. Survival outcomes were better in the MIDG group than in the ODG group (overall survival; $P=0.034$, relapse-free survival; $P=0.027$). In the multivariable analysis, ODG [hazard ratio (HR) 1.971, $P=0.046$], being 80 years or older (HR 2.285, $P=0.018$), male sex (HR 2.428, 95% $P=0.024$), and poor physical status (HR 2.324, $P=0.022$) were identified as independent prognostic factors for overall survival.

Conclusions We found that MIDG showed better efficacy than ODG in elderly gastric cancer patients. MIDG is an acceptable option for elderly patients.

Keywords Gastric cancer · Elderly patients · Minimally invasive gastrectomy · Distal gastrectomy · Efficacy · Propensity-score matched analysis

There is a growing need for minimally invasive surgery approaches for treating gastric cancer. In addition to safety merits [1, 2], they show equal efficacy compared to that of conventional open gastrectomy (OG) [3, 4]. A multicentre randomised controlled trial (RCT) in Japan demonstrated that laparoscopic distal gastrectomy (LDG) for clinical stage (cStage) I gastric cancer was non-inferior to open distal gastrectomy (ODG) [5]. Similar trials for cStage I gastric cancer conducted in Korea also demonstrated the non-inferiority of LDG [6]. Additionally, a Chinese trial for locally advanced gastric cancer demonstrated the non-inferiority of LDG [7]. As a further advanced procedure of the laparoscopic approach, robotic gastrectomy is expected to improve surgical outcomes while being extremely safe [8–10].

However, in these clinical trials, during which the evidence for these minimally invasive gastrectomy (MIG) was established, the majority of registered patients were middle-aged. Due to the recent increase in longevity [11], patients with gastric cancer are ageing [12]. Since clinical trials generally include highly selected, healthy patients, the external validity of the findings from these trials among the elderly remains unknown. The curative significance of MIG should be demonstrated among the elderly, as well as among younger or middle-aged patients. Comparative studies using the registry data of the Japanese National Clinical Database showed that laparoscopic gastrectomy was safer than open gastrectomy in the elderly [13]. We have also shown that the

✉ Masanori Terashima
m.terashima@scchr.jp

[1] Division of Gastric Surgery, Shizuoka Cancer Center, 1007 Shimonagakubo, Nagaizumi-cho, Sunto-gun, Shizuoka 411-8777, Japan

LDG procedure was as safe as ODG in patients who were not well [14]. However, the efficacy of MIG in the elderly has not yet been clearly demonstrated.

To clarify the significant impact of minimally invasive distal gastrectomy (MIDG) for the elderly, the present study compared the long-term outcomes between MIDG and ODG using propensity score matching since elderly patients have various individual differences in clinical and demographic characteristics [15].

Methods

This study included 427 patients aged 75 years or older who underwent gastrectomy for cStage I/IIA primary gastric cancer at the Shizuoka Cancer Centre from August 2008 to December 2016. We excluded 111 patients as follows: 81 patients who underwent total gastrectomy, 27 patients who underwent proximal gastrectomy, and three patients with pathological stage IV cancer. The patients were divided into two groups: those who underwent ODG and those who underwent MIDG. The surgical approach was decided upon according to the patient's preference. Among the remaining 316 patients, 144 patients underwent ODG and 172 underwent MIDG (including 137 laparoscopic and 35 robotic procedures). The clinical factors and outcomes were compared between these two groups. A flowchart of the enrolment and exclusion of cases is depicted in Fig. 1. Stage classification was determined according to the 8th American Joint Committee on Cancer/Union for International Cancer Control staging system [16]. This study was approved by the Institutional Review Board of Shizuoka Cancer Centre. Informed consent was substituted by the informed opt-out procedure due to the retrospective nature of the study and since the analysis used anonymous clinical data.

Data collection

The clinicopathological, surgical, and pathological findings were collected from a prospectively maintained database, as well as from individual patient medical records when necessary. The following data were obtained: patient characteristics (age, sex, body mass index [BMI]); preoperative physical status (the American Society of Anesthesiologists Physical Status, ASA-PS); preoperative performance status (the Eastern Cooperative Oncology Group Performance Status, ECOG-PS) and comorbidity; tumour characteristics; and surgical procedures (approach, type of resection, and dissection degree).

Operative and short-term postoperative outcomes were assessed, i.e. duration of operation, intraoperative blood loss, morbidity and mortality, and duration of postoperative hospital stay. Survival from the time of gastrectomy was calculated.

Definition of outcomes

Complications were graded according to the Clavien–Dindo classification (C–D) [17]. Postoperative complications in this study were defined as any adverse event corresponding to C–D grade II or greater, occurring within 30 days of gastrectomy. If a patient had more than one type of complication, the complication with the highest grade was used for the analysis.

The follow-up was scheduled according to our protocol. Briefly, in cases with advanced gastric cancer, patients were

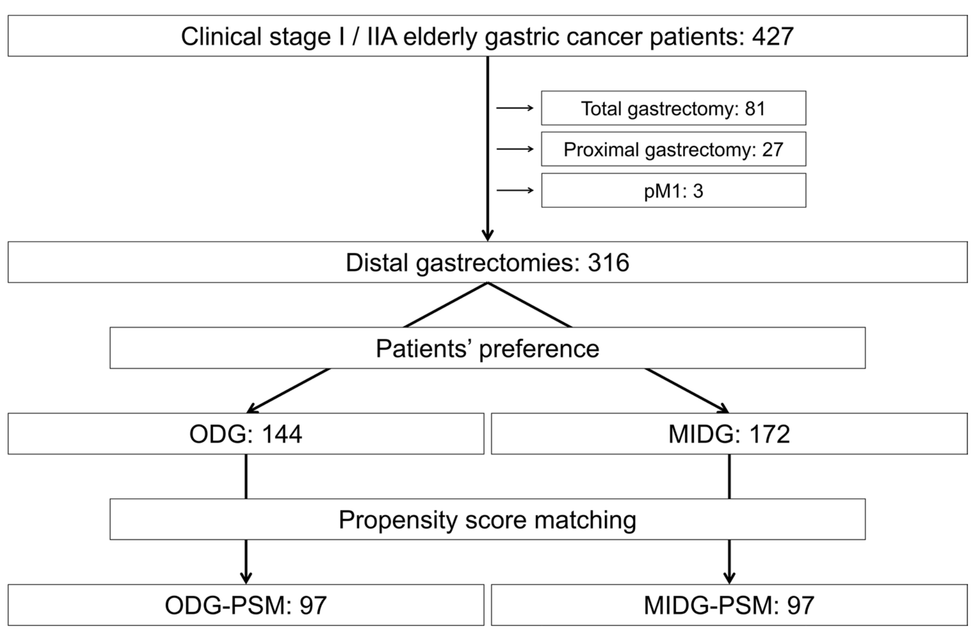

Fig. 1 Flow diagram depicting patient selection into the study. ODG open distal gastrectomy group, *MIDG* minimally invasive distal gastrectomy group, *ODG-PSM* open distal gastrectomy group after propensity score matching, *MIDG* minimally invasive distal gastrectomy group after propensity score matching

required to attend an outpatient clinic every 3 months for 3 years, and every 6 months thereafter for up to 5 years. In cases with early gastric cancer, patients were required to attend the clinic every 6 months for 3 years, and every year thereafter for up to 5 years. The follow-up data were updated in February 2020.

Propensity score matching and comparative analysis of matched groups

Propensity score matching analysis was performed using JMP software programme to remove confounding factors for incidences of peri- and postoperative events. Each patient's propensity score was calculated using a logistic regression model based on age, sex, BMI, ASA-PS, clinical T and N status, type of resection, and dissection degree, apart from outcomes. Patients in the ODG and MIDG groups were matched 1:1 using the nearest propensity score on the logit scale. All factors compared between the ODG and MIDG groups were also re-evaluated between the ODG-PSM and MIDG-PSM groups.

Statistical analyses

All continuous variables are presented as the median (range). Univariate and multivariable analyses of prognostic factors related to the survival were performed using the Cox proportional hazards model. Overall survival (OS), relapse-free survival (RFS), and disease-specific survival (DSS) rates were assessed using the Kaplan–Meier analysis with the log-rank test and the multivariable covariate-adjusted Cox model. Cumulative incidence rates in the covariate-adjusted model were calculated using competing risk survival statistics. Covariates with P values < 0.10 in the univariate analysis were entered into the multivariable analysis. All P values < 0.05 were considered statistically significant. All statistical analyses were performed using the JMP software programme (Version 11; SAS Institute, Cary, NC, USA) and R software version 3.6.3 (R Foundation for Statistical Computing, Vienna, Austria).

Results

Patient characteristics are summarised in Table 1. Patients in the ODG group had a higher BMI and a worse ASA-PS than those in the MIDG group. Moreover, the ODG group comprised a higher proportion of cT2 or node-positive patients than the MIDG group, whence D2 lymphadenectomy was more common in the ODG group than in the MIDG group. After propensity score matching, these discrepancies in patient characteristics disappeared (standardised difference 0.15 or less).

Short-term outcomes are shown in Table 2. The operative times were significantly longer in the MIDG group than in the ODG group (before matching; $P < 0.001$, after matching; $P < 0.001$, respectively), whereas blood loss was significantly higher in the ODG group than in the MIDG group ($P < 0.001$, $P < 0.001$, respectively). There were no differences in other short-term outcomes between the groups either before or after matching.

The pathological findings are reported in Table 3. The ratio of patients who had more advanced pathological status was higher in the ODG group before propensity matching analysis, but this difference was no longer significant after the matching. The MIDG group retrieved a higher number of lymph nodes than the ODG group.

Figure 2 shows the Kaplan–Meier curves in the propensity-matched cohort. The median follow-up periods were 4.7 (range 0.3–10.1) and 5.0 (range 0.4–10.7) years in the MIDG and ODG group, respectively. OS (Fig. 2A, $P = 0.034$) and RFS (Fig. 2B, $P = 0.027$) were significantly better in the MIDG group, while there was no significant difference in DSS between the groups (Fig. 2C, $P = 0.174$). The details regarding recurrence and causes of death within 5 years after the surgery are summarized in Table 4. Nine (9.3%) and four (4.1%) patients in the ODG and MIDG groups had recurrences, respectively. There were few local recurrences; two (2.1%) and one (1.0%) in the ODG and MIDG groups, respectively. The proportion of deaths due to other diseases was much higher than that due to gastric cancer-related deaths in both groups.

In the multivariable analysis, ODG [hazard ratio (HR) 1.971, 95% confidence interval (CI) 1.011–4.071, $P = 0.046$], being 80 years or older (HR 2.285, 95% CI 1.154–4.480, $P = 0.018$), male sex (HR 2.428, 95% CI 1.136–4.512, $P = 0.024$), and poor ASA-PS (HR 2.324, 95% CI 1.136–4.512, $P = 0.022$) were identified as independent prognostic factors for OS (Table 5). For the RFS, ODG (HR 2.007, 95% CI 1.055–4.030, $P = 0.033$), as well as being 80 years or older (HR 2.440, 95% CI 1.277–4.635, $P = 0.007$), male sex (HR 2.682, 95% CI 1.268–6.400, $P = 0.009$), and low BMI (HR 3.507, 95% CI 1.473–7.445, $P = 0.006$) were identified as independent prognostic factors (Table 6).

Figure 3 shows the covariate-adjusted survival curves using Cox regression models in the propensity-matched cohort. The covariate-adjusted OS (Fig. 3A, $P = 0.048$) and RFS (Fig. 3B, $P = 0.023$) were also significantly better in the MIDG group than in the ODG group.

Figure 4 shows the cumulative incidence rates of death in each group. There were no significant differences between the groups in the cumulative incidence of gastric cancer-related deaths (Fig. 4C, $P = 0.190$) and deaths due to other diseases (Fig. 4D, $P = 0.120$), respectively.

Table 1 Patient and tumour characteristics

	ODG ($n=144$)	MIDG ($n=172$)	P*	S.D.#	ODG-PSM ($n=97$)	MIDG-PSM ($n=97$)	P*	S.D.#
Age, years			0.429**	−0.04			0.337**	−0.12
Median (range)	78 (75–89)	78 (75–91)			78 (75–89)	78 (75–91)		
Sex			0.717	−0.04			0.877	−0.04
Male	100	116			68	66		
Female	44	56			29	31		
BMI, kg/m^2			0.001**	0.37			0.472**	−0.09
Median (range)	23.0 (15.9–33.5)	22.0 (15.1–36.7)			22.9 (15.9–33.5)	23.2 (15.1–36.7)		
ASA-PS			0.013	0.29			0.511	0.03
1	3	10			2	5		
2	111	144			78	76		
3	30	18			17	16		
ECOG-PS			0.816	0.03			0.919	0.06
0	108	132			74	74		
1	31	36			19	20		
2	5	4			4	3		
Diabetes mellites			0.483	0.09			1.000	0.03
Yes	32	32			21	20		
Cerebrovascular disease			0.617	−0.06			0.541	−0.12
Yes	17	24			12	16		
Respiratory impairment			0.569	−0.06			1.000	0.02
Yes	58	75			42	41		
Synchronous or metachronous malignancies			0.432	0.10			0.870	0.05
Yes	39	39			26	24		
Clinical T classification			< 0.001	0.58			0.828	0.06
cT1	103	160			84	86		
cT2	41	12			13	11		
Clinical N classification			0.026	0.27			1.000	0
cN0	135	170			95	95		
≥ cN1	9	2			2	2		
Clinical stage			0.026	0.27			1.000	0
I	135	170			95	95		
IIA	9	2			2	2		
Surgical approach			–				–	
Open	144	–			97	–		
Laparoscopic	–	137			–	79		
Robotic	–	35			–	18		
Extent of resection			0.849	−0.03			1.000	−0.04
Distal	131	155			86	85		
Pylorus-preserving	13	17			11	12		
Lymphadenectomy			< 0.001	0.71			1.000	0.03
D1+	87	154			78	79		
D2	57	18			19	18		

ODG open distal gastrectomy group, *MIDG* minimally invasive distal gastrectomy group, *ODG-PSM* open distal gastrectomy group after propensity score matching, *MIDG* minimally invasive distal gastrectomy group after propensity score matching, *BMI* Body mass index, *ASA-PS* American Society of Anesthesiologists Physical Status, *ECOG-PS* Eastern Cooperative Oncology Group Performance Status

*Chi-squared or Fisher's exact test, except **Mann–Whitney test

Table 2 Short-term outcomes before and after propensity score matching

	ODG (n = 144)	MIDG (n = 172)	P*	ODG-PSM (n = 97)	MIDG-PSM (n = 97)	P*
Operative time, min			< 0.001**			< 0.001**
Median (range)	205 (112–480)	292 (152–621)		203 (112–465)	296 (167–621)	
Estimated blood loss, ml			< 0.001**			< 0.001**
Median (range)	212 (25–2641)	20 (0–390)		194 (25–2641)	23 (0–310)	
All complication (Grade of C–D classification)			0.161			0.298
None	110	129		50	53	
II	26	29		22	18	
IIIa	5	10		3	8	
IIIb	2	0		2	0	
IVa	0	4		0	3	
IVb	0	0		0	0	
V	1	0		0	0	
Hospital stay, days			0.052**			0.124**
Median (range)	10 (7–73)	9 (7–71)		10 (7–73)	9 (7–51)	

ODG open distal gastrectomy group, *MIDG* minimally invasive distal gastrectomy group, *ODG-PSM* open distal gastrectomy group after propensity score matching, *MIDG* minimally invasive distal gastrectomy group after propensity score matching, *C–D* Clavien–Dindo

*Chi-squared or Fisher's exact test, except **Mann–Whitney test

Discussion

The present study demonstrated that MIDG was not only of equal safety, but also of superior efficacy compared with ODG in elderly gastric cancer patients. The patient characteristics were well-matched using propensity score matching, and there were also no significant differences in the degree of pathological progress between the groups after matching. Thus, straightforward comparisons could be made using this surgical approach. Therefore, we suggest that minimally invasive surgery should be selected preferentially for elderly gastric cancer patients.

Survival outcomes were significantly better in the MIDG group than in the ODG group in this study. In the multivariable analysis, ODG was selected as a risk factor of survival, along with additional factors including older age, male sex, poor ASA, and low BMI, all of which are generally accepted as survival risks [18–20]. Although the cohort included in this study was confined to cStage I/IIA patients, the risk of selecting an open surgery approach for the elderly was more harmful than the pathological progression. In previous phase III trials among patients of different ages, survival outcomes were nearly equal based on the different surgical approaches used [5, 6].

Postoperative complications are recognised as one of the most important factors affecting the surgical outcomes for gastric cancer patients [21]. We previously reported that intraabdominal infectious complication was an independent risk factor for survival in gastric cancer patients [22, 23]. It is uncertain whether MIG reduces postoperative complications compared to OG. Some studies reported that the incidence of complications after laparoscopic gastrectomies was significantly lower than that of conventional open surgeries [1, 2]; whereas another comparison made using data available in nationwide database, revealed that laparoscopic gastrectomies increased pancreatic-related complications [24]. In the present study, the incidence of complications was comparable between the groups, and was thus unable to explain the difference in survival outcomes.

The most probable reason for this discrepancy is the lower invasiveness of MIG. Although the patients in the MIDG group underwent operation for a longer duration, they lost less blood than the ODG group. Higher blood loss in the ODG group might be related to tissue destruction due to both numerous contacts by hands and dry conditions by exposure to the air through a large wound [25]. Previous RCTs performed in Japan were not able to prove the superior efficacy for highly invasive procedures such as the thoracoabdominal approach, bursectomy, and splenectomy in curative surgery for gastric cancer. These approaches rather had a tendency to lead to the worsening of survival outcomes [26–28]. Shorter postoperative hospital stays of laparoscopic gastrectomy in the previous studies supported lower damage caused [13, 29], and the present study also showed the same trend. A previous RCT also showed that ODG significantly worsened the quality of life (QOL) even after discharge from a hospital [30]. In general, physiological reserve capacity decreased with advancing age, which predicted eventual

Table 3 Pathological findings

	ODG ($n=144$)	MIDG ($n=172$)	*P**	ODG-PSM ($n=97$)	MIDG-PSM ($n=97$)	*P**
Differentiation (dominant)			0.269			0.716
Differentiated	103	111		67	64	
Undifferentiated	39	60		28	32	
Special	2	1		2	1	
Retrieved lymph nodes (pieces)			< 0.001			0.003
Median	30	36		30	37	
Range	13–79	13–93		13–79	13–86	
Pathological T classification			0.002			0.479
pT1	109	156		83	86	
pT2	17	7		7	5	
pT3	11	8		5	6	
pT4a	7	1		2	0	
Pathological N classification			0.131			0.788
pN0	107	146		82	79	
pN1	21	16		8	12	
pN2	11	7		4	4	
pN3	5	3		3	2	
Pathological stage			0.032			0.984
IA	92	137		74	74	
IB	20	18		12	13	
IIA	13	9		4	5	
IIB	9	5		3	2	
IIIA	7	2		2	2	
IIIB	3	1		2	1	
IIIC	0	0		0	0	

ODG open distal gastrectomy group, *MIDG* minimally invasive distal gastrectomy group, *ODG-PSM* open distal gastrectomy group after propensity score matching, *MIDG* minimally invasive distal gastrectomy group after propensity score matching

*Chi-squared or Fisher's exact test, except **Mann–Whitney test

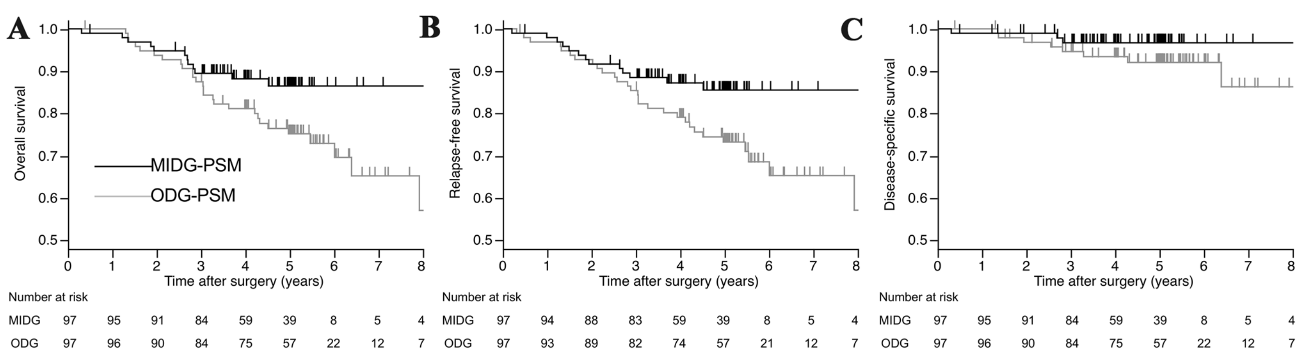

Fig. 2 Survival after open *versus* minimally invasive distal gastrectomy in gastric cancer patients in the propensity-matched cohort. **A** Overall survival; $P=0.034$, **B** relapse-free survival; $P=0.027$, **C** disease-specific survival; $P=0.174$ (log rank test)

death from other diseases [31]. In our study cohort, the proportion of deaths due to other diseases was also much higher. Prolonged harmful influence during the postoperative period might be one of the reasons for the poor survival in the ODG group observed in this study.

In fact, the MIDG group had lower HRs for the cumulative incidence of death due to both other diseases and that related to gastric cancer. However, this difference was not statistically significant likely due to the insufficient power. MIDG was not disadvantageous for elderly

Table 4 Recurrence and causes of death in the propensity-matched cohort

	ODG-PSM (*n* = 97)	MIDG-PSM (*n* = 97)
Recurrence *n* (%)	9 (9.3)	4 (4.1)
Hematogenous	5 (5.2)	3 (3.1)
Liver	5 (5.2)	2 (2.1)
Lung	2 (2.1)	2 (2.1)
Other	2 (2.1)	–
Distant lymphatic	5 (5.2)	1 (1.0)
Peritoneal	3 (3.1)	–
Local	2 (2.1)	1 (1.0)
Dead *n* (%)	23 (23.7)	12 (12.4)
Gastric cancer	7 (7.2)	3 (3.1)
Other disease	16 (16.5)	9 (9.3)
Other malignancies	4 (4.1)	2 (2.1)
Cardiac failure	4 (4.1)	3 (3.1)
Cerebrovascular disease	3 (3.1)	–
Pneumonia	2 (2.1)	3 (3.1)
Neurodegeneration	2 (2.1)	–
Digestive disorder	1 (1.0)	–
Renal failure	–	1 (1.0)

Both the recurrence patterns and causes of death observed within 5 years following the surgery were recorded. Values in parentheses indicate percentages

ODG-PSM open distal gastrectomy group after propensity score matching, *MIDG* minimally invasive distal gastrectomy group after propensity score matching

patients regarding survival or the relapse rate compared with ODG. No previous study has shown the critical risk of MIG which requires the cessation of these procedures. Therefore, it is considered to be quite reasonable to try to reduce the invasiveness of gastrectomy for elderly gastric cancer patients using MIDG.

In the future, further improvements in the effects of gastric cancer surgery are expected. Although the procedures in the ODG group remained largely unchanged for the study period, the MIDG group included cases, in which the surgery was performed in the early days of these procedures. Nevertheless, the higher number of dissected lymph nodes and the lower HRs for the RFS, suggested sufficient surgical precision in the MIDG group. Since the number of study patients was relatively small in the present study, it was difficult to compare the relative merits of the laparoscopic and the robotic gastrectomy. The application of MIG has been increasing with ever-improving technology of devices and the proceeding of standardisation [32]. Based on the favourable safety reported in previous studies [8–10], robotic gastrectomy will become the mainstream for MIG [33]. It is hoped that the increased use of these developing less-invasive surgeries will greatly contribute to improvement in the overall outcomes among gastric cancer patients.

The present study has certain limitations. Firstly, this was a retrospective study in a single institute, although the patients were highly comparable between groups. Secondly, this study did not include patients who underwent total or proximal gastrectomy because the number of these MIG cases during the study period was limited. Thirdly, our study lacked an evaluation of perioperative life quality due to the difficulty of establishing a fixed methodology.

In conclusion, the present study showed the survival advantage of MIDG for elderly patients with cStage I/IIA gastric cancer compared with conventional ODG. Although the results from this retrospective study are hard to confirm the superiority of the efficacy in MIG, which remains a matter of debate, MIG might be valuable for elderly gastric cancer patients.

Table 5 Risk factors of overall survival analysed using the Cox proportional hazards model in the propensity-matched cohort

Variable	Univariate analysis			Multivariable analysis		
	HR	(95% CI)	*P*	HR	(95% CI)	*P*
Approach						
Minimally invasive						
Open	2.057	(1.067–4.214)	0.031	1.971	(1.011–4.071)	0.046
Age (years)						
75–79						
≥ 80	2.033	(1.028–3.868)	0.041	2.285	(1.154–4.480)	0.018
Sex						
Female						
Male	2.313	(1.085–5.707)	0.029	2.428	(1.136–4.512)	0.024
BMI (kg/m^2)						
≥ 18.5						
< 18.5	2.083	(0.130–4.634)	0.130			
ASA-PS score						
1–2						
3	2.848	(1.419–5.430)	0.004	2.324	(1.136–4.512)	0.022
ECOG-PS score						
0–1						
2	2.049	(0.332–6.743)	0.374			
Complication (Grade of C–D classification)						
0–II						
≥ III	2.174	(0.818–4.841)	0.111			
Pathological stage						
IAB						
≥ II	2.181	(0.929–4.541)	0.071	1.666	(0.691–3.565)	0.239

HR hazard ratio, *95% CI* 95% confidence interval, *BMI* body mass index, *ASA-PS* American Society of Anesthesiologists Physical Status, *ECOG-PS* Eastern Cooperative Oncology Group Performance Status, *C–D* Clavien–Dindo

Table 6 Risk factors of relapse-free survival analysed using the Cox proportional hazards model in the propensity-matched cohort

Variable	Univariate analysis			Multivariable analysis		
	HR	(95% CI)	*P*	HR	(95% CI)	*P*
Approach						
Minimally invasive						
Open	2.057	(1.092–4.094)	0.025	2.007	(1.055–4.030)	0.033
Age (years)						
75–79						
≥ 80	2.106	(1.117–3.946)	0.022	2.440	(1.277–4.635)	0.007
Sex						
Female						
Male	2.138	(1.042–4.967)	0.038	2.682	(1.268–6.400)	0.009
BMI (kg/m^2)						
≥ 18.5						
< 18.5	2.924	(1.255–6.011)	0.015	3.507	(1.473–7.445)	0.006
ASA-PS score						
1–2						
3	2.493	(1.254–4.688)	0.011	1.734	(0.847–3.359)	0.128
ECOG-PS score						
0–1						
2	1.838	(0.299–6.018)	0.443			
Complication (Grade of C–D classification)						
0–II						
≥ III	2.033	(0.768–4.495)	0.141			
Pathological stage						
IAB						
≥ II	2.514	(1.126–5.053)	0.026	2.160	(1.126–5.053)	0.065

HR hazard ratio, *95% CI* 95% confidence interval, *BMI* body mass index, *ASA-PS* American Society of Anesthesiologists Physical Status, *ECOG-PS* Eastern Cooperative Oncology Group Performance Status, *C–D* Clavien–Dindo

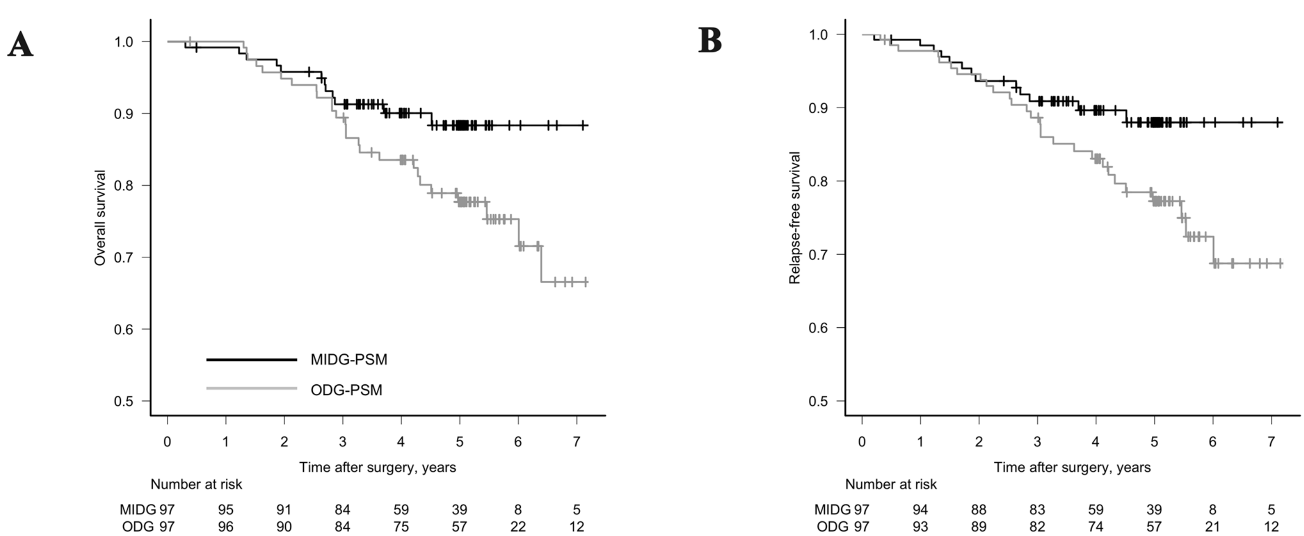

Fig. 3 Covariate-adjusted survival after open *versus* minimally invasive distal gastrectomy in the propensity-matched cohort. **A** Covariate-adjusted overall survival; the adjusted hazard ratio (HR) for ODG based on the Cox regression analysis was 2.004 [95% confidence interval (CI) 1.007–3.988, $P=0.048$], **B** Covariate-adjusted relapse-free survival; the HR for ODG based on the Cox regression analysis was 2.064 (95% CI 1.065–3.997, $P=0.032$)

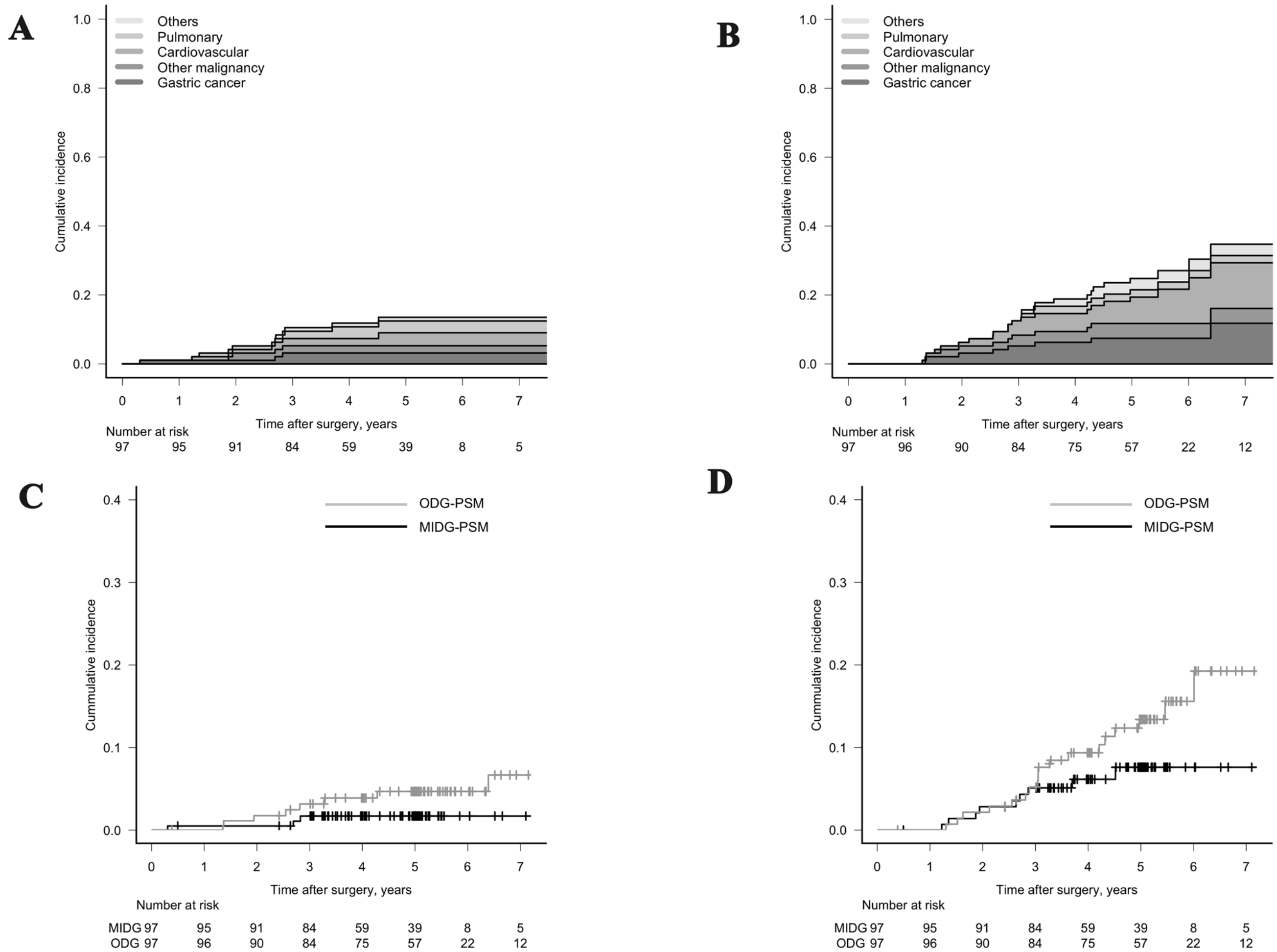

Fig. 4 Cumulative incidence of mortality after open *versus* minimally invasive distal gastrectomy in the propensity-matched cohort. **A** Cumulative incidence rates of death after MIDG. **B** Cumulative incidence rates of death after ODG. **C** Covariate-adjusted cumulative incidence curves of gastric cancer-related death are shown. The 5-year cumulative incidence of gastric cancer-related death was 1.7% [95% confidence interval (CI) 0.4–6.5%] for the MIDG group and 4.7% (95% CI 1.8–11.4%) for the ODG group. The adjusted hazard ratio (HR) for ODG based on the competing risk regression analysis was 2.669 (95% CI 0.618–11.530, $P=0.190$). **D** Covariate-adjusted cumulative incidence curves for death due to other diseases are shown. The 5-year cumulative incidence for death due to other diseases was 7.7% (95% CI 3.5–16.3%) for the MIDG group and 13.4% (95% CI 7.4–23.7%) for the ODG group. The adjusted HR for ODG was 1.855 (95% CI 0.856–4.022, $P=0.120$)

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Compliance with ethical standards

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