

Difficult biliary cannulation in ERCP procedures with or without trainee involvement: a comparative study

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ABSTRACT

Background The 5–5–1 criteria (>5 minutes – 5 cannulation attempts – 1 unintended pancreas duct cannulation) were proposed by the European Society of Gastrointestinal Endoscopy to define difficult biliary cannulation. However, the criteria may be inappropriate for trainee-involved procedures. We developed criteria for difficult cannulation in trainee-involved procedures.

Methods Patients undergoing biliary cannulation with or without trainee involvement were eligible. Procedures that might be too easy (e. g. fistula) or too difficult (e. g. altered anatomy) were excluded. The primary outcome was difficult cannulation, defined as cannulation time, attempts, or inadvertent pancreatic duct (PD) cannulation exceeding the 75% percentile of each variable. Propensity score matching (PSM) analysis was used.

Results After PSM, there were 1596 patients in each group. Trainee-involved procedures had longer median (interquartile range [IQR]) cannulation time (7.5 [2.2–15.3] vs. 2.0 [0.6–5.2] minutes), and more attempts (5 [2–10] vs. 2 [1–4]) and inadvertent PD cannulation (0 [0–2] vs. 0 [0–1]) vs. procedures without trainee involvement (all $P < 0.001$). The 15–10–2 criteria for difficult cannulation were proposed for trainee-involved cannulation and the 5–5–1 criteria were nearly confirmed for cannulation without trainee involvement. The proportions of difficult cannulation using these respective criteria were 35.5% (95% confidence interval [CI] 33.2%–37.9%) and 31.8% (95%CI 29.5%–34.2%), respectively (odds ratio 1.18 [95%CI 1.02–1.37]). Incidences of post-ERCP pancreatitis following difficult cannulation were comparable (7.8% [95%CI 5.7%–10.3%] vs. 9.8% [95%CI 7.4%–12.8%], respectively).

Conclusion By using the 75% percentiles as cutoffs, the proposed 15–10–2 criteria for difficult cannulation could be appropriate in trainee-involved procedures.

Introduction

Selective deep cannulation is a critical step for the performance of endoscopic retrograde cholangiopancreatography (ERCP). The incidence of difficult biliary cannulation has been reported in many studies [1–3], ranging from 10% to 40% in patients

with native papilla. Difficult cannulation is an independent risk factor for post-ERCP pancreatitis (PEP) [4]. PEP incidence has been reported to be 8%–12% in patients with difficult cannulation [3, 5], whereas it is 3%–5% in patients without difficult cannulation [4]. When the cannulation proves difficult, advanced cannulation techniques are often necessary, including the dou-

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ble-guidewire technique, transpancreatic sphincterotomy, or needle-knife precut [6].

The European Society of Gastrointestinal Endoscopy has proposed the 5–5–1 criteria for the definition of difficult cannulation: >5 minutes spent attempting to cannulate, >5 contacts with the papilla to cannulate, >1 unintended PD cannulation or opacification [7]. The clear definition of difficult cannulation is important for making decisions during or after ERCP, including determining the appropriate time to transfer to advanced cannulation techniques and whether prophylactic methods should be administered to reduce the risk of PEP [1, 8]. Although the 5–5–1 criteria [7] have been widely used during ERCP practice or in relevant studies, it remains unclear whether these criteria are suitable for cannulation procedures involving trainees. Because of inexperienced manipulation of the scope and accessories, the involvement of trainees generally increases the overall cannulation time and number of cannulation attempts, which are two important variables in the criteria of difficult cannulation. Thus, we hypothesized that the definition of difficult cannulation in trainee-involved procedures might be different from the traditional 5–5–1 criteria.

To develop the criteria of difficult cannulation in trainee-involved ERCP, we retrospectively analyzed the data associated with cannulation procedures with or without trainee involvement. We also compared the proportion of difficult cannulation, PEP incidence, and the frequency of advanced cannulation techniques in patients with predicted difficult cannulation between the proposed criteria in trainee-involved procedures and the traditional 5–5–1 criteria in procedures without trainee involvement.

Methods

Patients

This was a retrospective study including consecutive patients with native papilla who underwent elective ERCP at Xijing Hospital in China. On average, 1300 ERCP procedures are performed each year at this tertiary center. Patient-related and procedure-related data were retrieved from a prospectively maintained database. The study protocol was approved by the Institutional Review Board of Xijing Hospital (KY20202067-F-1).

Among all originally approached patients, those not providing consent and those without a native papilla were not included in the study. Patients were also excluded if they were considered unsuitable for this study of difficult cannulation, such as: 1) with indications of major or minor pancreatic duct (PD) cannulation; 2) without attempts of cannulation due to inaccessible papilla; 3) undergoing cannulation via papillary fistula; 4) with duodenal stenosis or anatomical deformity secondary to prior surgery.

Five trainers from our center were involved in the study. All of them had experience of more than 1500 ERCPs and completed 150–350 ERCPs per year. A total of 28 trainees involved in the 1-year ERCP training were involved in the study. All of the trainees specialized in the gastrointestinal field and had no prior ERCP experience (see **Table 1** s in the online-only Supplementary material). Before performing biliary cannulation in

patients, trainees attended didactic lectures on ERCP, which included anatomy of the pancreaticobiliary system, introduction to ERCP, and basic techniques including handling of the duodenoscope and accessories, selective cannulation, contrast injection, and sphincterotomy. They then practiced insertion of the duodenoscope, manipulation of accessories, and observed clinical ERCP cases for approximately 100 cases before starting cannulation training. In about the first 20 cases, new trainees began their cannulation training in patients with previous endoscopic sphincterotomy, before being allowed to attempt cannulation in patients with native papilla.

ERCP procedures

ERCP was performed with propofol sedation or general anesthesia. Duodenal relaxation was achieved with scopolamine butylbromide (Buscopan, Boehringer Ingelheim, Ingelheim am Rhein, Germany). Based on whether trainees were involved in the initial cannulation procedures, patients were divided into the trainee group or the non-trainee group. During cannulation training, trainees were allowed to attempt biliary cannulation for 10 minutes under the supervision of one of five experienced trainers (including oral instructions and/or hands-on assistance), as described in our previous report [9]. An experienced endoscopist would take over the scope and continue the cannulation procedure if the trainee failed to cannulate within 10 minutes.

Selective biliary cannulation was initially performed with a guidewire-assisted cannulation technique. Advanced cannulation methods were chosen at the discretion of the experienced endoscopist, and included double-guidewire cannulation, precut with needle-knife or dual knife, transpancreatic or over-the-stent precut. After successful cannulation was finally achieved by trainees themselves or by trainers, trainees were allowed to perform further post-cannulation manipulations under the supervision of trainers.

Outcomes

The primary outcome of the study was difficult cannulation. Cannulation was considered difficult if the values of cannulation time, cannulation attempts, or inadvertent PD cannulation exceeded the 75% percentile of each cannulation-related variable. Secondary outcomes included incidences of PEP and overall adverse events, and the proportion of procedures requiring advanced cannulation methods.

Definition

The total cannulation time was counted from the beginning of contact with the papilla to deep cannulation of the common bile duct (CBD). A cannulation attempt was defined as the sphincterotome touching the papilla for at least 5 seconds.

PEP and other ERCP-related adverse events (bleeding, infection, cholangitis, and perforation) together with severity grades were classified based on the American Society for Gastrointestinal Endoscopy criteria [10]. Rectal indomethacin (100 mg), prophylactic PD stent placement, and/or aggressive hydration with Ringer's solution could be used for PEP prevention at the discretion of the endoscopists.

► **Table 1** Baseline characteristics before and after propensity score matching.

	Unmatched patients				Patients after PSM			
	Trainee group (n = 1742)	Non-trainee group (n = 2673)	OR (95%CI)	P*	Trainee group (n = 1596)	Non-trainee group (n = 1596)	OR (95%CI)	P*
Age, median (IQR), years	61 (49–70)	63 (51–74)		<0.001	61 (50–70)	61 (48–72)		0.74
Female, n (%)	907 (52.1)	1358 (50.8)	1.05 (0.93–1.19)	0.41	831 (52.1)	848 (53.1)	0.96 (0.83–1.10)	0.55
BMI, median (IQR), kg/m ²	22.5 (20.4–25.0)	22.5 (20.3–24.8)		0.41	22.5 (20.4–25.0)	22.5 (20.4–24.9)		0.87
CBD stone, n (%)	1297 (74.5)	1860 (69.6)	1.27 (1.11–1.46)	<0.001	1186 (74.3)	1210 (75.8)	0.92 (0.79–1.08)	0.33
Biliary stricture, n (%)	255 (14.6)	539 (20.2)	0.71 (0.60–0.84)	<0.001	247 (15.5)	230 (14.4)	1.09 (0.90–1.32)	0.40
Suspected SOD, n (%)	41 (2.4)	33 (1.2)	1.93 (1.21–3.06)	0.005	32 (2.0)	29 (1.8)	1.11 (0.67–1.84)	0.70
Others, n (%)	149 (8.6)	241 (9.0)	0.94 (0.76–1.17)	0.60	131 (8.2)	127 (8.0)	1.03 (0.80–1.33)	0.80
History of acute pancreatitis, n (%)	37 (2.1)	67 (2.5)	0.84 (0.56–1.27)	0.41	110 (6.9)	108 (6.8)	1.02 (0.78–1.34)	0.89
Periampullary diverticulum, n (%)	497 (28.5)	550 (20.6)	1.54 (1.34–1.77)	<0.001	435 (27.3)	410 (25.7)	1.08 (0.93–1.27)	0.32

PSM, propensity score matching; OR, odds ratio; CI, confidence interval; IQR, interquartile range; BMI, body mass index; CBD, common bile duct; SOD, sphincter of Oddi dysfunction.

* P value < 0.05 was considered significant.

Statistical analyses

Categorical variables were described as frequency rates and percentages with 95% confidence intervals (CIs). Continuous variables were described as mean and standard deviation (SD) when variables were normally distributed, or median and interquartile range (IQR) when variables were not normally distributed. The chi-squared test was used to compare categorical variables. Results were presented as odds ratios (ORs) with 95% CIs, which were computed using univariate regression. Nonparametric Wilcoxon–Mann–Whitney test or Student’s *t* test was used to compare continuous variables. In an effort to reduce potential bias, a propensity score matching (PSM) analysis was performed. Propensity scores to determine matched pairs between the groups were created using nine variables that could potentially influence the cannulation difficulty: age, sex, body mass index, ERCP indications (CBD stone, biliary stricture, suspected sphincter of Oddi dysfunction, and others), previous history of acute pancreatitis, and periampullary diverticulum. The propensity scores were then calculated using a logistic regression model. Patients were matched in a 1:1 ratio using a caliper width of 0.01 with nearest-neighbor matching without replacement.

Statistical analyses were performed using IBM SPSS version 22.0 (IBM Corp, Armonk, New York, USA) and figures were generated using GraphPad Prism 8.02 or Python 3.7. All tests were two-sided, and a *P* value of less than 0.05 was considered statistically significant.

Results

Patients

From January 2014 to December 2019, 4894 patients who underwent ERCP and had available data related to cannulation procedures were screened for the study. After screening, 479 patients were excluded, including 259 patients with indications for PD cannulation, 13 with an inaccessible papilla, 61 with cannulation via the papillary fistula, and 146 with duodenal stenosis or altered anatomy secondary to prior surgery. Finally, 4415 patients were included in the study, with 1742 patients in the trainee group and 2673 in the non-trainee group. After PSM, there were 1596 patients in each group (**Fig. 1 s**). Baseline characteristics before and after PSM are shown in ► **Table 1**. Background demographic details were similar in the two groups. The most common indication for ERCP was CBD stones (about 75%).

Cannulation procedure and ERCP-related adverse events

Procedure-related variables and adverse events are shown in ► **Table 2** and **Table 2s**. The overall cannulation success was 99.4%. Cannulation-related variables were quite different between the two groups. Compared with the non-trainee group, patients in the trainee group had a longer median cannulation time (7.5 [IQR 2.2–15.3] vs. 2.0 [IQR 0.6–5.2]; *P* < 0.001), more

► **Table 2** Procedure-related variables and endoscopic retrograde cholangiopancreatography-related adverse events.

Characteristic	Overall (n = 3192)	Trainee group (n = 1596)	Non-trainee group (n = 1596)	OR (95%CI)	P*
Overall cannulation success, n (%)	3173 (99.4)	1586 (99.4)	1587 (99.4)	0.90 (0.37–2.22)	0.82
Successful cannulation of trainees, n (%)		898 (56.3)			
Standard cannulation, n (%)	2650 (83.0)	1276 (79.9)	1374 (86.1)	0.64 (0.53–0.78)	<0.001
Advanced cannulation method, n (%)	542 (17.0)	320 (20.1)	222 (13.9)	1.55 (1.29–1.87)	<0.001
▪ DGW	180 (5.6)	135 (8.5)	45 (2.8)	3.19 (2.26–4.50)	<0.001
▪ Precut	374 (11.7)	196 (12.3)	178 (11.2)	1.12 (0.90–1.38)	0.32
▪ Transpancreatic	201 (6.3)	126 (7.9)	75 (4.7)	1.74 (1.30–2.33)	<0.001
▪ Needle-knife	173 (5.4)	70 (4.4)	103 (6.5)	0.67 (0.49–0.91)	0.01
Total cannulation time, median (IQR), minutes	3.4 (1.0–11.4)	7.5 (2.2–15.3)	2.0 (0.6–5.2)		<0.001
Cannulation attempts, median (IQR), n	3 (1–7)	5 (2–10)	2 (1–4)		<0.001
Inadvertent PD cannulation, median (IQR), n	0 (0–1)	0 (0–2)	0 (0–1)		<0.001
PEP prophylaxis measures, n (%)					
▪ Prophylactic PD stent	286 (9.0)	207 (13.0)	79 (4.9)	2.86 (2.19–3.75)	<0.001
▪ Indomethacin	1906 (59.7)	1116 (69.9)	790 (49.5)	2.37 (2.05–2.74)	<0.001
Overall adverse events, n (%)	257 (8.1)	122 (7.6)	135 (8.5)	0.90 (0.69–1.16)	0.40
▪ Acute pancreatitis	182 (5.7)	86 (5.4)	96 (6.0)	0.89 (0.66–1.20)	0.45
▪ Mild	141 (4.4)	69 (4.3)	72 (4.5)	0.96 (0.68–1.34)	0.80
▪ Moderate to severe	41 (1.3)	17 (1.1)	24 (1.5)	0.71 (0.38–1.32)	0.27
▪ Bleeding	41 (1.3)	28 (1.8)	13 (0.8)	2.17 (1.12–4.21)	0.02
▪ Biliary infection	57 (1.8)	22 (1.4)	35 (2.2)	0.62 (0.36–1.07)	0.08

OR, odds ratio; CI, confidence intervals; DGW, double-guidewire; IQR, interquartile range; PD, pancreatic duct; PEP, post-ERCP pancreatitis; ERCP, endoscopic retrograde cholangiopancreatography.

* P value <0.05 was considered significant.

median cannulation attempts (5 [IQR 2–10] vs. 2 [IQR 1–4]; $P < 0.001$), and more median inadvertent PD cannulation (0 [IQR 0–2] vs. 0 [IQR 0–1]; $P < 0.001$) (► **Fig. 1**).

In the trainee group, successful cannulation was achieved by trainee alone in 56.3% (898/1596) of patients. The median time, and cannulation attempts, and inadvertent PD cannulation were 2.6 (IQR 1.1–5.2) minutes, 2 (IQR 1–4), and 0 (IQR 0–1), respectively. For the remaining 698 patients with failed cannulation by trainees within 10 minutes, the trainers took over the procedure. The median time, cannulation attempts, and inadvertent PD cannulation of successful cannulations were 16.7 (IQR 12.7–25.6) minutes, 11 (IQR 8–15), and 1 (IQR 0–4), respectively, and the final success rate was 98.6% (688/698) by trainers after trainees failed.

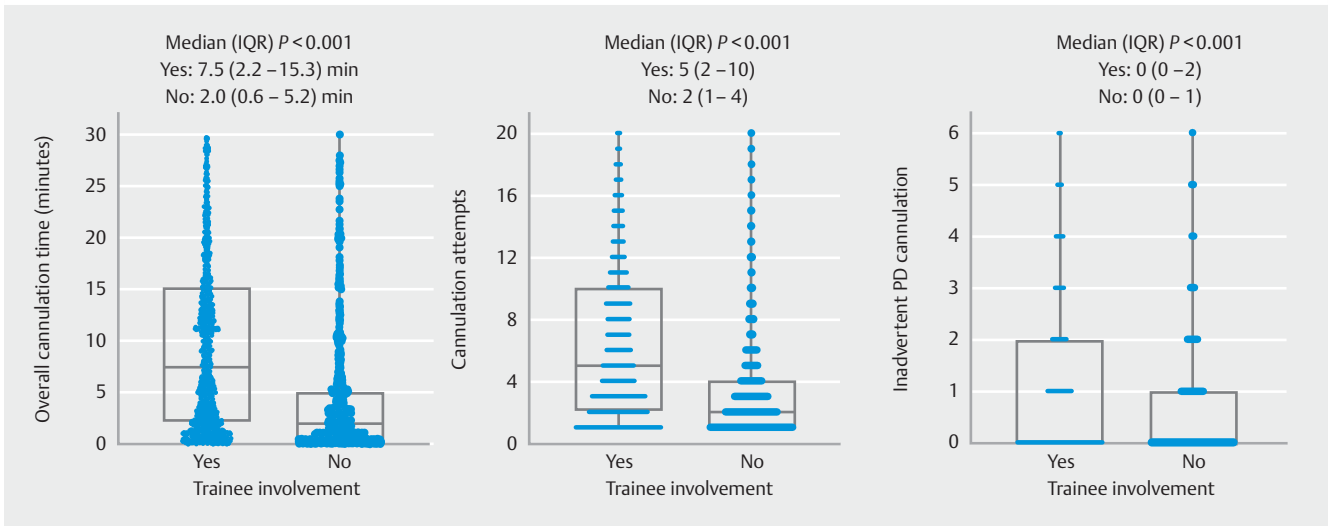
Patients in the trainee group received more advanced cannulation methods (20.1% [95%CI 18.1%–22.1%] vs. 13.9% [95%CI 12.2%–15.7%]), including double-guidewire technique (8.5% [95%CI 7.1%–9.9%] vs. 2.8% [95%CI 2.1%–3.8%]) and transpancreatic precut (7.9% [95%CI 6.6%–9.3%] vs. 4.7% [95%CI 3.7%–5.9%]). Although prophylactic PD stent (13.0% [95%CI 11.4%–14.7%] vs. 4.9% [95%CI 3.9%–6.1%]) and rectal

indomethacin (69.9% [95%CI 67.6%–72.2%] vs. 49.5% [95%CI 47.0%–52.0%]) were more frequently used in the trainee group compared with the non-trainee group, the PEP incidence was similar between the two groups (5.4% [95%CI 4.3%–6.6%] vs. 6.0% [95%CI 4.9%–7.3%]; OR 0.89 [95%CI 0.66–1.20]).

Proposed difficult cannulation criteria

According to the current criteria for difficult cannulation (5–5–1) [7], the proportion of cannulation procedures that were difficult was significantly higher in the trainee group than in the non-trainee group (61.9% [95%CI 59.5%–64.3%] vs. 31.8% [95%CI 29.5%–34.2%]). However, the incidence of PEP (6.5% [95%CI 5.0%–8.2%] vs. 9.8% [95%CI 7.4%–12.8%]; OR 0.63 [95%CI 0.43–0.93]) and the frequency of advanced cannulation methods (31.2% [95%CI 28.3%–34.2%] vs. 35.8% [95%CI 31.7%–40.2%]; OR 0.81 [95%CI 0.65–1.02]) in patients with difficult cannulation were or tended to be lower in the trainee group than in the non-trainee group (► **Table 3**).

Percentiles of cannulation procedures in the two groups are described in ► **Fig. 1**. The 75% percentile of cannulation time, cannulation attempts, and inadvertent PD cannulation in the



► **Fig. 1** Cannulation-related variables of patients in the trainee and non-trainee groups after propensity score matching. IQR, interquartile range; PD, pancreatic duct.

► **Table 3** Difficult cannulation in the two groups based on 5–5–1 criteria.

	Trainee group (n = 1596)	Non-trainee group (n = 1596)	OR (95%CI)	P*
Difficult cannulation, n (%)	988 (61.9)	508 (31.8)	3.48 (3.01–4.03)	<0.001
▪ PEP, n (%)	64 (6.5)	50 (9.8)	0.63 (0.43–0.93)	0.02
▪ Advanced cannulation methods, n (%)	308 (31.2)	182 (35.8)	0.81 (0.65–1.02)	0.07
▪ DGW	128 (13.0)	31 (6.1)	2.29 (1.52–3.44)	<0.001
▪ Precut	191 (19.3)	152 (29.9)	0.56 (0.44–0.72)	<0.001

OR, odds ratio; CI, confidence intervals; PEP, post-ERCP pancreatitis; ERCP, endoscopic retrograde cholangiopancreatography; DGW, double-guidewire.
* P value <0.05 was considered significant.

non-trainee group were 5.2 minutes, 4, and 1, respectively. These three values of cannulation procedures were almost the same as the current 5–5–1 criteria of difficult cannulation. For the 1596 patients in the trainee group, the 75% percentile of successful cannulation could be achieved within 15.3 minutes, 10 cannulation attempts, or 2 inadvertent PD cannulations. Therefore, we proposed that 15–10–2 criteria could be used to define difficult cannulation in the trainee group. Percentages of procedures that exceeded the 15–10–2 and 5–5–1 criteria are shown in **Fig. 2s**.

When the 15–10–2 criteria were used in the trainee group and the 5–5–1 criteria were used in the non-trainee group, the proportion of difficult cannulation was 35.5% (95%CI 33.2%–37.9%) in the trainee group and 31.8% (95%CI 29.5%–34.2%) in the non-trainee group (OR 1.18 [95%CI 1.02–1.37]). There was a similar incidence of PEP (7.8% [95%CI 5.7%–10.3%] vs. 9.8% [95%CI 7.4%–12.8%]; OR 0.77 [95%CI 0.50–1.18]) and overall adverse events (10.4% [95%CI 8.0%–13.2%] vs. 13.6% [95%CI 10.7%–16.9%]; OR 0.74 [95%CI 0.51–1.07]) between the two groups. There were more uses of advanced cannulation methods (44.6% [95%CI 40.5%–48.8%] vs. 35.8% [95%CI

31.7%–40.2%]; OR 1.44 [95%CI 1.13–1.85]) in the trainee group (► **Table 4, Table 3s**).

Simplification of the two criteria

To simplify the two criteria, the number of cannulation attempts was removed, as it was significantly correlated with overall cannulation time in the two groups (**Fig. 3s**). The simplified 5–1 criteria (5 minutes for cannulation time and 1 inadvertent PD cannulation) were comparable to the traditional 5–5–1 criteria with regard to the proportion of difficult cannulation, PEP incidence, and the rate of using advanced cannulation methods in the non-trainee group (all $P > 0.1$). In the trainee group, the simplified 15–2 criteria (15 minutes for cannulation time and 2 unintended PD cannulations) were also comparable to the 15–10–2 criteria in PEP incidence and the rate of using advanced cannulation methods (► **Fig. 2, Table 4s**).

Discussion

This study first used 75 percentiles of cannulation-related variables as cutoff values to define difficult cannulation. The analy-

Table 4 Performance of procedure-related variables with the 15–10–2 criteria in the trainee group and the 5–5–1 criteria in the non-training group.

	Trainee group (n = 1596) ¹			Non-trainees group (n = 1596) ²			P ⁴	OR (95%CI)	P ³
	Difficult cannulation (n = 567, 35.5%)	Non-difficult cannulation (n = 1029, 64.5%)	OR (95%CI)	Difficult cannulation (n = 508, 31.8%)	Non-difficult cannulation (n = 1088, 68.2%)	OR (95%CI)			
Advanced cannulation methods, n (%)	253 (44.6)	67 (6.5)	11.57 (8.59–15.58)	182 (35.8)	40 (3.7)	14.63 (10.16–21.05)	<0.001	1.44 (1.13–1.85)	0.003
▪ DGW	94 (16.6)	41 (4.0)	4.79 (3.27–7.02)	31 (6.1)	14 (1.3)	4.99 (2.63–9.46)	<0.001	3.06 (2.00–4.68)	<0.001
▪ Precut	167 (29.5)	29 (2.8)	14.40 (9.55–21.71)	152 (29.9)	26 (2.4)	17.44 (11.31–26.89)	<0.001	0.98 (0.75–1.27)	0.87
PEP prophylaxis measures, n (%)									
▪ Prophylactic PD stent	159 (28.0)	48 (4.7)	7.97 (5.65–11.22)	63 (12.4)	16 (1.5)	9.49 (5.42–16.60)	<0.001	2.75 (2.00–3.80)	<0.001
▪ Indomethacin	449 (79.2)	667 (64.8)	2.07 (1.63–2.63)	290 (57.1)	500 (46.0)	1.56 (1.27–1.93)	<0.001	2.86 (2.19–3.74)	<0.001
Overall adverse events, n (%)	59 (10.4)	63 (6.1)	1.78 (1.23–2.58)	69 (13.6)	66 (6.1)	2.43 (1.71–3.47)	<0.001	0.74 (0.51–1.07)	0.11
▪ PEP	44 (7.8)	42 (4.1)	1.98 (1.28–3.06)	50 (9.8)	46 (4.2)	2.47 (1.63–3.75)	<0.001	0.77 (0.50–1.18)	0.23
▪ Mild	33 (5.8)	36 (3.5)	1.71 (1.05–2.77)	37 (7.3)	35 (3.2)	2.36 (1.47–3.80)	<0.001	0.79 (0.48–1.28)	0.33
▪ Moderate-to-severe	11 (1.9)	6 (0.6)	3.37 (1.24–9.17)	13 (2.6)	11 (1.0)	2.57 (1.14–5.78)	0.018	0.75 (0.33–1.70)	0.49
▪ Bleeding	11 (1.9)	17 (1.7)	1.18 (0.55–2.53)	7 (1.4)	6 (0.6)	2.52 (0.84–7.54)	0.087	1.42 (0.55–3.68)	0.47
▪ Cholangitis	12 (2.1)	10 (1.0)	2.20 (0.95–5.13)	16 (3.1)	19 (1.7)	1.83 (0.93–3.59)	0.075	0.67 (0.31–1.42)	0.29

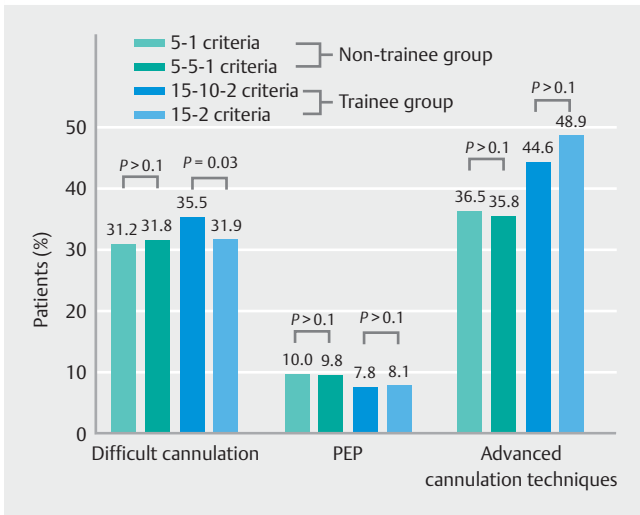
OR, odds ratio; CI, confidence intervals; DGW, double-guidewire; PEP, post-ERCP pancreatitis; ERCP, endoscopic retrograde cholangiopancreatography; PD, pancreatic duct.

¹ Difficult cannulation was defined by the 15–10–2 criteria

² Difficult cannulation was defined by the 5–5–1 criteria.

³ P value for the comparisons of difficult cannulation columns between the trainee and non-trainee groups.

⁴ P value < 0.05 was considered significant.



► **Fig. 2** Comparisons of standard/proposed criteria with simplified criteria regarding proportion of difficult cannulation, incidence of post-endoscopic retrograde cholangiopancreatography pancreatitis (PEP), and rate of advanced cannulation techniques (defined by nonstandard cannulation with wire-guided sphincterotome, such as double-guidewire cannulation, precut with needle-knife or dual knife, transpancreatic or over-the-stent precut) after propensity score matching.

sis showed that difficult cannulation could be defined by 5–4–1 criteria in 1596 patients undergoing cannulation without trainee involvement. This result was almost the same as the traditional 5–5–1 criteria, with a similar proportion of cannulations that were difficult (31.8%) and similar PEP incidence (9.8%) in patients with difficult cannulation compared with previous studies [3, 5].

Compared with the non-trainee group, the trainee group had longer cannulation times, more cannulation attempts, more inadvertent PD cannulation, and a higher frequency of using advanced cannulation methods. It could be expected therefore that more PEP might occur in the trainee group. However, PEP prophylaxis was used in more patients in the trainee group (rectal indomethacin 69.9% vs. 49.5%; PD stent 13.0% vs. 4.9%), and was generally based on the current criteria of difficult cannulation and followed the recommendations of several guidelines [1, 4]. As a result of this effective prevention in the current study, PEP incidence in the trainee group was not significantly different from that in the non-trainee group. Furthermore, overall PEP incidence in this study was 5.7%, which was comparable to the 3%–12% in previous reports [4, 9, 11–14].

Some circumstances can potentially impact the results of the difficulty of cannulation. For the procedures with trainee involvement, individual performance competency of trainees [15] and lifetime procedure count [16] may affect the difficulty of cannulation. Individual performance competency was difficult to evaluate objectively, and lifetime procedure counts were not available owing to the respective nature of this study. The proposed 15–10–2 criteria of difficult cannulation in trainee-involved procedures might be biased by the cannulation

competency of different trainees or by the different stages of ERCP training.

The current study was based on a prospectively maintained ERCP database in a tertiary hospital, which included the information on whether trainees were involved in initial cannulation, data related to the cannulation procedure, as well as baseline characteristics of trainees. Unfortunately, information on when and which trainees participated in the cannulation were not routinely recorded, which made it impossible to draw a learning curve of selective cannulation in native papilla for each trainee. As time goes on during ERCP training, trainees could become increasingly familiar with cannulation of the native papilla. The rates of difficult or failed cannulation in trainee-involved ERCP may thus be different in the early stages compared with the late stages of training, as revealed by several previous studies [15–18]. The definition of difficult cannulation in trainee-involved procedures may be influenced by the learning curve effect. Therefore, it would be valuable to further investigate, in large prospective cohorts, whether the 15–10–2 criteria are still useful for defining difficult cannulation at different stages of hands-on ERCP training.

The 15–10–2 criteria reflected the performance of both the trainee and the supervising trainer, which compromised the validity of the findings. Trainee-involved cannulation is a team effort. For the trainee involved in failed cannulation procedures, the corresponding metrics of trainees and trainers could be evaluated separately. However, the respective criteria might have limited clinical relevance as the outcomes of ERCP were influenced by the combined performance of the trainee and the trainer. The criteria of difficult cannulation have been widely used to determine whether PEP prophylaxis should be administered and when advanced cannulation methods should be considered. The proportion of cannulations that were difficult, incidence of PEP, and overall adverse event rate seem comparable between results determined by the 15–10–2 criteria in the trainee group and the 5–5–1 criteria in the non-trainee group. We believe the 15–10–2 criteria could be a useful tool to determine difficult cases with trainee-involved cannulation, and deserve to be further validated in different training centers.

During cannulation procedures, time is highly related to the number of cannulation attempts, with a positive correlation confirmed in our study. Although many studies use cannulation attempts as an indicator to judge difficult cannulation, there is no uniform definition of a cannulation attempt. The recording of the cannulation attempts is more tedious than cannulation time and requires an additional investigator to watch the video in real time or retrospectively to obtain accurate values. A previous study found that compared with the number of attempts to cannulate the papilla, cannulation time was a more objective and more accurate assessment tool for grading cannulation difficulty [19]. In the current study, following simplification of the criteria, there was no significant difference between the original and simplified criteria that omitted the number of cannulation attempts (5–5–1 vs. 5–1 and 15–10–2 vs. 15–2) in terms of the proportion of difficult cannulation (only for 5–1 vs. 5–5–1), PEP incidence, and the use of advanced cannulation techniques

(► **Fig. 2**), indicating that the simplification was a reasonable proposal.

The present study has some limitations. First, although data analysis was based on a large sample size of patients undergoing ERCP, not all of the originally approached patients were included, and a lack of relevant information makes it impossible to determine whether there were any differences between those who were included and those who were not. Furthermore, 8.4% (146/1742) of patients in the trainee group were not included after PSM. Therefore, selection bias should be considered when interpreting the results. Second, the individual cannulation skills of the trainees were different, which might affect the variables related to the cannulation procedure. However, skill is difficult to evaluate objectively. Whether ERCP was elective or an emergency may also influence the difficulty of cannulation. However, the current study only enrolled patients undergoing elective ERCP. Although adverse events of PEP, cholangitis, and bleeding occurred in this study, the 30-day mortality data were not available. Third, the novel criteria for difficult cannulation in trainee-involved ERCP cannulation procedures were not validated by internal and external cohorts owing to current limitations in resources. The reliability of the criteria deserves to be further validated in order to provide more credible evidence for wide acceptance of these novel criteria in clinical practice.

In conclusion, the 15–10–2 criteria were proposed to define difficult cannulation with trainee involvement and demonstrated performance that was similar to the 5–5–1 criteria used with non-trainee procedures. The simplified 5–1 criteria and 15–2 criteria seemingly had comparable efficacy for the evaluation of difficult cannulation compared with the traditional criteria.

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Competing interests

The authors declare that they have no conflict of interest.

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