Hong Kong J Radiol. 2021;24:192-200 | https://doi.org/10.12809/hkjr2116952

ORIGINAL ARTICLE

Radiation Dose Reduction for Endoscopic Retrograde Cholangiopancreatography: An Initiative for Patient and Endoscopist Radiation Safety

KY Man, KH Lui, KY Cho

Department of Radiology, Pamela Youde Nethersole Eastern Hospital, Hong Kong

ABSTRACT

Objectives: *To evaluate the effectiveness of a practical dose reduction measure for endoscopic retrograde cholangiopancreatography (ERCP) and to ensure the radiation dose is maintained in line with well-established international reference levels.*

Methods: *Between January 2017 and July 2017, 50 ERCP examinations were retrospectively evaluated to estimate the patient radiation doses received while undergoing ERCP examinations in a tertiary referral centre in Hong Kong before and after implementation of radiation dose reduction measures by adjusting the acquisition parameters on the fluoroscopy machine in the designated fluoroscopic suite. Statistical analysis was performed on dose area product. We also assessed the fluoroscopy time, the number of spot images taken during the examination, the quality of the diagnostic radiographic images, and the outcome of the ERCP (including technical success rate and complications).*

Results: *A significant reduction (53.4%) in dose area product was achieved at the end of the study. The fluoroscopy time, the number of spot images taken, the quality of the diagnostic radiographic images, and the outcome of ERCP before and after implementation of dose reduction measures did not show any significant differences.*

Conclusion: *A significant reduction in radiation dose to patients undergoing ERCP was achieved after implementation of a simple practical dose reduction measure in our hospital, without lengthening fluoroscopy time, or compromising image quality or outcome.*

Key Words: *Cholangiopancreatography, endoscopic retrograde; Fluoroscopy; Radiation exposure; Radiometry*

Correspondence: *Dr KY Man, Department of Radiology, Pamela Youde Nethersole Eastern Hospital, Hong Kong*
Email: dsgundam@hotmail.com

Submitted: 16 Jan 2018; Accepted: 24 Aug 2018

Contributors: KYM designed the study. KYM and KHL acquired the data. KYM analysed the data and drafted the manuscript. All authors critically revised the manuscript for important intellectual content. All authors had full access to the data, contributed to the study, approved the final version for publication, and take responsibility for its accuracy and integrity.

Conflicts of Interest: All authors have disclosed no conflicts of interest.

Funding/Support: This study received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Data Availability: All data generated or analysed during the present study are available from the corresponding author on reasonable request.

Ethics approval: This study was approved by the Hong Kong East Cluster Research Ethics Committee (Ref HKECREC-2017-061). The patients were treated in accordance with the tenets of the Declaration of Helsinki. The patients provided written informed consent for all treatments and procedures.

中文摘要

降低內窺鏡逆行胰膽管造影術的放射劑量：關於患者和內窺鏡醫師放射安全的一個倡議措施

文家潤、呂錦浩、曹君彥

目的：評估內窺鏡逆行胰膽管造影（ERCP）的實際劑量減少措施的有效性，並確保輻射劑量與公認的國際參考水平保持一致。

方法：於2017年1月至2017年7月期間，在香港三級轉診中心進行ERCP檢查時通過調整指定透視套房內透視機上的採集參數，對50次ERCP檢查進行回顧性評估，以估計在實施減少輻射劑量措施前後患者接受的輻射劑量。對劑量面積乘積進行統計分析。我們同時評估透視時間、檢查期間拍攝的點圖像數量、診斷性放射圖像質量，以及ERCP結果（包括技術成功率和併發症）。

結果：在研究結束時實現了劑量面積乘積的顯著減少（53.4%）。實施劑量減少措施前後的ERCP在透視時間、拍攝的點片圖像數量，以及診斷性放射圖像質量均沒有顯示出任何顯著差異。

結論：在我們醫院實施簡單實用的劑量降低措施後，接受ERCP的患者的輻射劑量顯著降低，而不延長透視時間也不影響圖像質量或結果。

INTRODUCTION

Ionising radiation is sometimes used during endoscopic procedures, most frequently during endoscopic retrograde cholangiopancreatography (ERCP). With increasing public awareness and concern surrounding radiation risks, it is crucial that procedures be performed according to the "as low as reasonably achievable" (ALARA) principle.

Several previous studies have proposed dose reduction measures during ERCP by adding protective lead shields or drapes,[1-3] but this may involve additional manipulation of patients or changes in equipment positioning. For example, when the shield is used, exposure of endoscopists to radiation was reduced to 17% for diagnostic procedures and to <7% for therapeutic procedures.[1] However, the shield may interfere with the manipulation of catheters and wires or affect fluoroscopic or videoendoscopic visualisation during the procedure.

We aimed to evaluate the effectiveness of a dose reduction technique involving the adjustment of acquisition parameters on the fluoroscopy machine. We also aimed to determine if this adjustment affected the length of fluoroscopy due to decreased image quality.

METHODS

To formulate a dose reduction goal, a national dose survey was used as a reference.[4] The means of dose area products (DAPs) for diagnostic and therapeutic ERCPs are 4 and 10 Gycm^2, respectively. The mean fluoroscopy times for diagnostic and therapeutic ERCP are 2.6 and 4.4 minutes, respectively.

Study Design

A retrospective review of radiation doses received by patients undergoing ERCP examinations from January 2017 to July 2017 in a local tertiary referral centre was performed, before (standard dose) and after (low dose) implementation of radiation dose reduction measures. Two phases of the study have been conducted. The first phase consisted of an audit of radiation dose for ERCP from January to May 2017 (standard dose). These data were used as a baseline reference representing normal practices before implementation of dose reduction measures. Endoscopists were not aware that the study was being undertaken. After implementation of radiation dose reduction measures, an audit of the low-dose cohort from May 2017 to July 2017 was performed. Radiological and clinical records of ERCP performed in these periods were retrospectively reviewed.

The major outcomes were radiation dose, ERCP outcome, and image quality. Data including patient demographics, DAP (Gycm^2), fluoroscopy time (min), number of spot images taken during examinations, procedure indication, difficulty, complications, technical success, and image quality were collected.

The radiation doses were recorded from the fluoroscopic machine display. The clinical variables related to the ERCP were retrieved through dedicated electronic patient records in our institution. Two independent radiologists assessed the image quality.

Study Population

Adult patients (aged >18 years) who underwent ERCP were included. The patients were referred from various departments within the hospital. All ERCPs were clinically indicated.

To estimate the sample size, we performed an a priori sample size estimation with the G-Power 3.1.0 (power: 0.8; α: 0.05) by using data from a previous study that examined radiation dose reduction during ERCP,[3] with a calculated effect size of 1 (Cohen's d). It was estimated that at least 18 subjects in each group would be sufficient.

From January 2017 to May 2017 and May 2017 to July 2017, records of 25 consecutive patients who underwent ERCP for the standard and 25 consecutive patients for the low-dose ERCP examination groups were reviewed.

Fluoroscopic Examinations and Acquisition Parameters

All examinations were performed in our fluoroscopic suite (Artis zee multi-purpose system; Siemens, München, Germany).

Table 1 shows the detailed acquisition parameters before and after dose reduction for ERCP. Parameters were adjusted based on two aspects: dose reduction and image quality. It is generally thought that the image quality may be compromised in a low-dose setting; we aimed to compensate for this effect.

Table 1. Major fluoroscopic acquisition parameters for standard and low-dose ERCP settings.*

	Standard ERCP fluoroscopic setting	Low-dose ERCP fluoroscopic setting
Fluoroscopic tube voltage, kVp	73	81
Dose (dose per image)	55 nGy per pulse	36 nGy per pulse
kV dose	109 kV	90 kV
Edge enhancement	15%	20%
iNoise reduction	Normal	Smooth
Digital density optimisation	70%	55%
Kernel		
K-factor	Auto 5	Auto 6
Pulse rate, fps	7.5	7.5

Abbreviation: ERCP = endoscopic retrograde cholangiopancreatography.

* Some of the parameters are manufacturer-specific terms (Artis zee multi-purpose system).

The changes were discussed with the manufacturer and application specialists. In order to achieve ALARA, it seemed unnecessary to use the relatively high-dose settings currently in use to achieve an adequate image quality for biliary tree evaluation. The proposed changes to the protocol to reduce the dose were discussed and agreed by an expert panel in the Working Group on Radiation Safety in our institution. The local Institutional Review Board approved this study.

The endoscopists, including hepatobiliary team surgeons and gastrointestinal physicians, performed approximately 1000 ERCP procedures in the year prior to the study at our institution. All endoscopists were unaware that the study, with changes to protocol parameters, was being undertaken.

Among the available metrics for radiation exposure, DAP was appropriate for monitoring patient radiation dose.[5] DAP is defined as the absorbed dose multiplied by the X-ray beam cross-sectional area at the point of measurement. Our fluoroscopic machine was equipped with a DAP meter. The DAP was shown on the live screen in the examination room, on the data display in the examination room, and on the console monitor in the control room. The DAP meter was calibrated at regular intervals.

Procedure Indication, Intent, and Difficulty

Although related, procedure indication and intent were distinct issues. The indication related to the reason for the procedure. The intent was the goal for a specific procedure. For example, an ERCP might be indicated in a patient with obstructive jaundice, whereas the intent could be either to find the cause of jaundice (diagnostic) or to relieve the jaundice (therapeutic). It was necessary to assess indication and intent because both were integral components of determining procedure success.

ERCP difficulty was determined by a published grading system that was developed for the assessment of ERCP outcomes.[6] All ERCPs are classified into three levels based on the technical difficulty of each manoeuvre (Table 2). This classification provides a simple and objective measure of the clinical complexity of an ERCP and may also provide a measure of procedure risk. The difficulty of a procedure was also important for assessing procedure success.

Table 2. Grading system for technical difficulty in endoscopic retrograde cholangiopancreatography.

	Procedures
Grade 1	Biliary cytology, pancreatic cytology, standard sphincterotomy ± removal of stones <10 mm, stricture dilatation/stent for extrahepatic stricture
Grade 2	Billroth II anatomy, removal of common bile duct stones >10 mm, minor papilla cannulation, stricture dilatation/stent for hilar tumours or benign intrahepatic strictures
Grade 3	Endoscopic therapy in Billroth II anatomy, removal of intrahepatic stones, pseudocyst drainage or any stones requiring lithotripsy

Complications and Technical Success

The specific method of identifying and collecting unplanned events/complications remains controversial for ERCP.[6] Complications such as pancreatitis or perforation are obvious and should be tracked. The significance of other events associated with the procedure remains unclear. Further research is required before the optimal method to record delayed complications can be firmly established. Nevertheless, unplanned events were tracked in our study.

Technical success was based on the technical difficulty of ERCP. Thus, technical success was stratified based on technique and described as complete success (diagnostic and therapeutic), partial success (access to desired duct with incomplete or partial therapy) or failed (failure to access or drain the desired duct). For example, a simple cannulation was not sufficient to represent success in cases where basic therapeutic measures were necessary.

Image Quality Evaluation

To the best of our knowledge, there are no objective quality criteria for ERCP radiographic images to date. In order to better assess the quality of ERCP radiographic images, we adopted the quality criteria for urinary tract radiographic images before and after administration of contrast medium according to a published guideline,[7] with some modifications for the biliary tract (Table 3). Subjective evaluation of image quality was also performed using a scoring system, with particular attention to image contrast and noise, ranking from 0 to 4 (Table 3).

Two independent radiologists were aware of the clinical information and assessed the image quality of the spot ERCP radiographic images of different patients in randomised order. They were blinded to each other's results and the parameters used to acquire the images (both the low-dose and standard-dose protocols). They were asked to record the image quality score according to the above proposed criteria. All images were reviewed on a dedicated workstation (Carestream PACS Workstation, Carestream, Genova, Italy).

Statistical Analysis

Statistical analysis was performed with commercially available statistical software SPSS (Windows version 22.0; IBM Corp, Armonk [NY], United States). Comparison of demographics, radiation dose, ERCP outcome, and image quality were done with *t* test, Mann-Whitney *U* test, or Chi-square test as appropriate.

Standard multiple regression was used to identify any possible predictors/confounding factors for DAP.

Table 3. Modified quality criteria for ERCP radiographic images and subjective image quality criteria.

Modified quality criteria of ERCP radiographic images (adapted from a published guideline[7]) [can have a score from 0-3; score 1 point if any of the following feature is fulfilled]	Subjective image quality (can have a score from 0-4)
A: Opacification of the entire biliary tract (including the gallbladder, intrahepatic ducts, common bile duct and duodenal region);	4 – Excellent image quality: excellent opacification of biliary tree, excellent guidewire visualisation, absent or minimal image noise
B: Visually sharp reproduction of the bones;	3 – Good image quality: mild image noise, good biliary tree opacification and guidewire visualisation
C: After administration of contrast medium, the following should be assessed: visually sharp reproduction of the area normally traversed by biliary tract (tailored to individual patient, e.g., visually sharp reproduction of unobstructed intrahepatic ducts or common bile duct)	2 – Moderate image quality: moderate image noise but not interfering with diagnostic quality
	1 – Bad image quality: too much noise or faint opacification of biliary tree which may interfere with diagnostic quality
	0 – Very bad image quality: severe noise, undetectable biliary tree opacification of guidewire manipulation, not useful for diagnostic purpose

Abbreviation: ERCP = endoscopic retrograde cholangiopancreatography.

Relevant variables known to have an association with DAP were included in the model. Age, body mass index (BMI), fluoroscopy time, number of spot images taken, and ERCP difficulty grade were added into the regression model as predictors. A general linear model was performed to mitigate any potential confounding effects of the confounders on DAP. Statistical significance for all of the tests was set at $p < 0.05$.

Inter-observer agreement of the image quality scores were assessed using the kappa statistic. The κ strengths were categorised as follows: <0.20, poor; 0.21 to 0.40, fair; 0.41 to 0.60, moderate; 0.61 to 0.80, good; and 0.81 to 1.00, very good.

RESULTS

Radiation Dose Reduction

The median DAP was 13.0 $Gycm^2$ for standard ERCP settings and 6.1 $Gycm^2$ for low-dose ERCP settings. The difference in median DAP between the two groups was statistically significant (Mann-Whitney *U* test, $p < 0.001$). The median DAP for the low-dose examination was 53.4% lower than the standard-dose examination (Table 4).

There were no statistically significant differences in age, gender, height, weight, or BMI between the two groups (Chi-square test or *t* test, $p > 0.05$). There were also no statistically significant differences in fluoroscopy time and number of spot images taken between the two groups (*t* test and Mann-Whitney *U* test, respectively; Table 4).

In the regression model with DAP as the dependent variable (adjusted R square = 0.561, $p < 0.001$), BMI (standardised beta = 0.233, $p = 0.031$), number of spot images taken (standardised beta = 0.334, $p = 0.004$), and fluoroscopy time (standardised beta = 0.481, $p < 0.001$) made statistically significant contributions to the prediction of the dependent variable.

A general linear model was conducted to further explore differences in DAP between the two groups while controlling for possible covariates/confounders. BMI, number of spot images taken, and fluoroscopy time were used as covariates in the analysis of DAP. After adjusting for the above-named covariates/confounders, there was a statistically significant difference in DAP between the two groups (adjusted R squared = 0.652, $p < 0.001$).

Endoscopic Retrograde Cholangiopancreatography Procedural Variables

All ERCPs were performed for therapeutic purposes. Nearly half of the ERCPs were performed for follow-up (e.g., after removal of a stent). There were no statistically significant differences in ERCP degree of difficulty, complication rate, or technical success rate between the standard and low-dose examination groups (Chi-square test, $p > 0.05$) [Table 5]. Median follow-up time for post-ERCP complication was 3 months (range, 2-6 months). For patients with complications following ERCP, none of them was definitely attributed to the low-dose setting.

Image Quality Evaluation

Radiographic and subjective image quality evaluation (Figures 1-3) by the two independent radiologists showed no significant difference in the scores among the

Table 4. Comparison of patients' demographic and fluoroscopic examination variables.*

Variables	Total (n = 50)	Standard ERCP setting (n = 25)	Low-dose ERCP setting (n = 25)	p Value
Sex				0.248†
Male	30 (60%)	13 (52%)	17 (68%)	
Female	20 (40%)	12 (48%)	8 (32%)	
Age, y	69.3 ± 14.9	66.4 ± 14.1	72.2 ± 15.3	0.423‡
Height, cm	161.2 ± 8.8	160.5 ± 6.9	161.8 ± 10.5	0.053‡
Weight, kg	59.7 ± 14.2	61.7 ± 14.1	57.7 ± 14.3	0.429‡
BMI, kg/m^2	22.9 ± 4.7	23.8 ± 4.9	21.9 ± 4.3	0.141‡
Dose area product, μGym^2	782.9 (1301.9)	1297.2 (1548.2)	604.9 (417.5)	<0.001§
Fluoroscopy time, min	6.7 ± 4.7	6.6 ± 4.7	6.9 ± 4.8	0.697‡
No. of spot radiographic images taken	6 (3)	6 (4)	6 (3)	0.806§

Abbreviations: BMI = body mass index; ERCP = endoscopic retrograde cholangiopancreatography.
* Data are shown as No. (%) of patients, mean ± standard deviation, or median (interquartile range).
† Chi-square test.
‡ Independent-samples *t* test.
§ Mann-Whitney *U* test.

Table 5. Comparison of ERCP procedural variables.

Variables	Total (n = 50)	Standard ERCP setting (n = 25)	Low-dose ERCP setting (n = 25)	p Value
Indication				N/A
Cholangitis	9 (18%)	9 (36%)	0	
Abnormal imaging	14 (28%)	5 (20%)	9 (36%)	
Deranged liver function	4 (8%)	4 (16%)	0	
Follow-up ERCP (e.g., remove stent)	23 (46%)	7 (28%)	16 (64%)	
ERCP degree of difficulty grades				0.078*
Grade 1	25 (50%)	10 (40%)	15 (60%)	
Grade 2	13 (26%)	10 (40%)	3 (12%)	
Grade 3	12 (24%)	5 (20%)	7 (28%)	
Presence of complication				1.0*
No	48 (96%)	24 (96%)	24 (96%)	
Yes	2 (4%)	1 (4%)†	1 (4%)‡	
Technical success				1.0*
Complete success	46 (92%)	23 (92%)	23 (92%)	
Partial success	3 (6%)	2 (8%)	1 (4%)	
Failed	1 (2%)	0	1 (4%)§	

Abbreviations: ERCP = endoscopic retrograde cholangiopancreatography; N/A = not applicable.

* Chi-square test.

† 1 patient in the standard examination group experienced a cardiopulmonary complication.

‡ 1 patient in the low-dose examination group developed contrast nephropathy.

§ 1 ERCP in the low-dose examination group was aborted due to an oedematous papilla with a linear ulcer, in which the ampulla opening could not be identified.

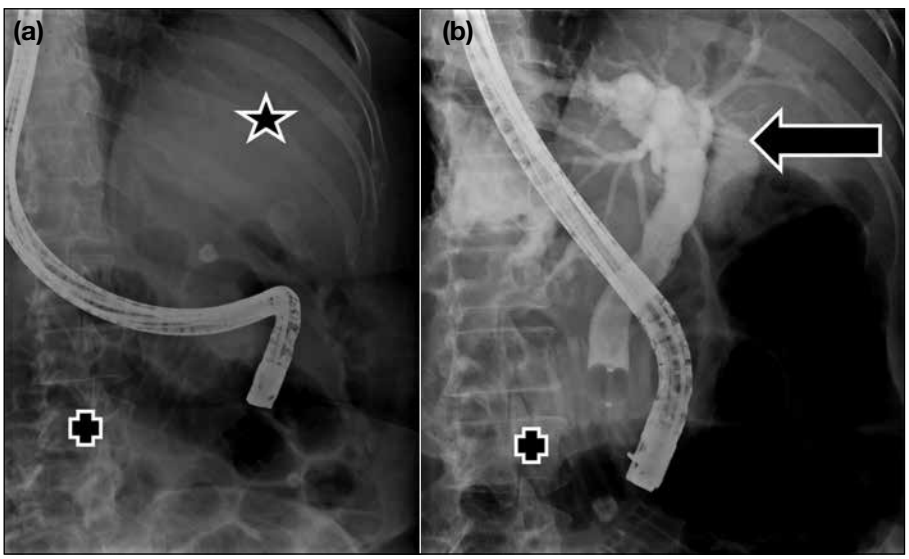

Figure 1. Radiographic image quality evaluation by modified quality criteria. (a) Whole biliary tract including the gallbladder, intrahepatic ducts, common bile duct, and duodenal region (star). (a, b) Sharp reproduction of the bones (crosses). (b) After administration of contrast medium, the following should be assessed: sharp reproduction of the biliary tract, tailored to the individual patient, (e.g., sharp unobstructed intrahepatic ducts or common bile ducts) [arrow].

two patient groups (Chi-square test, $p > 0.05$). The inter-observer agreement on modified image quality criteria and subjective image quality were good (kappa = 0.669 and 0.722, respectively) [Table 6].

DISCUSSION

The two basic principles of radiation protection of the patient as recommended by the International Commission on Radiological Protection are justification of practice and optimisation of protection, including the consideration of dose reference levels. Justification is the first step in radiation protection. It is accepted that no diagnostic exposure is justifiable without a valid clinical indication, no matter how good the imaging performance may be. Every examination must result in a net benefit for the patient. This only applies when it can be anticipated that the examination will influence the clinical decision with respect to the following: diagnosis,

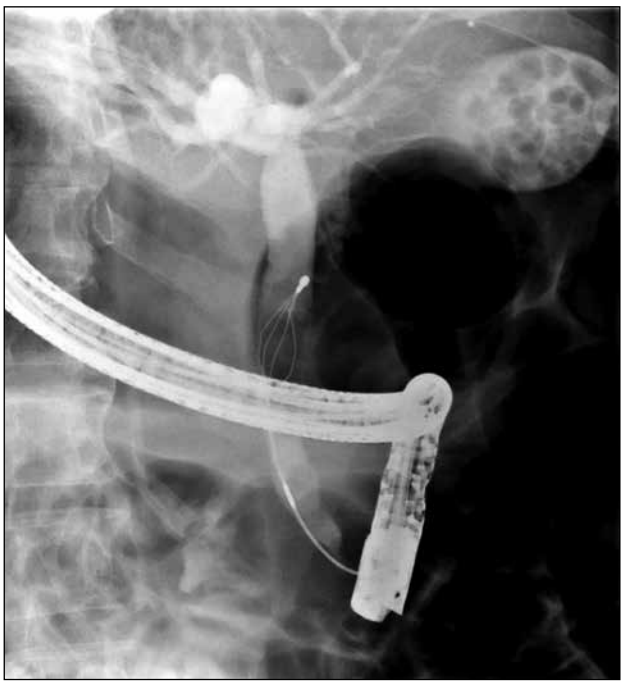

Figure 2. Subjective image quality evaluation. Excellent image quality: excellent opacification of biliary tree, excellent guidewire visualisation, absent or minimal image noise.

patient management and therapy, and final outcome for the patient.

With respect to diagnostic examinations, the International Commission on Radiological Protection does not recommend the application of dose limits to patient irradiation but draws attention to the use of dose reference levels as an aid to optimisation of protection in medical exposure. Once a diagnostic examination has been clinically justified, the subsequent imaging process must be optimised. The optimal use of ionising radiation involves the interplay of three important aspects of the imaging process: the diagnostic quality of the radiographic image, the radiation dose to the patient, and the choice of radiographic technique.

Radiation dose to patients during ERCP depends on many factors.[5] Some factors are related to the endoscopist, including fluoroscopy time, number of digital spot images taken, and use of collimation. The endoscopist cannot control some variables, such as patient size or procedure type (diagnostic vs. interventional). Other factors are intrinsic to the equipment. For instance, pulsed fluoroscopy, whereby the X-ray beam is turned on and off at a fixed rate, can significantly reduce exposure without having the X-ray beam on continuously[8]; copper X-ray beam filtration, which limits patient dose from low-energy X-rays; fluoroscopic loop review, and last-image hold options that allow review of images without additional X-ray exposure. There is often a trade-off between image quality and radiation exposure. For example, choosing a low dose may result in a noisy image, especially for an obese patient, so for such patients, the endoscopist will often choose a medium- or high-dose setting.

In our study, radiation and image acquisition parameters were adjusted. For radiation parameters, the fluoroscopic tube voltage was increased from 73 kVp to 81 kVp. The fluoroscopic tube voltage in kV was maintained automatically for as long as possible. For extremely thin or small patients, the kV value was reduced. In case of lower transparency (thicker objects), the kV value would be increased to ensure correct image brightness. It was recommended by the manufacturer to set the X-ray tube voltage as high as possible (not forgetting the image quality and image contrast). It is reported that a high kV technique (80-100 kV) could reduce the dose to a patient up to 50%, compared to the conventional technique (75-96 kV).[8] The dose in the scanning protocol parameters refers to dose per spot image. It was a nominal value which applied to the measuring conditions at 70 kV, 2.1-mm Cu pre-filtering, 16-cm flat detector input field. It was decreased from 55 nGy per pulse to 36 nGy per pulse, which decreased the dose from every single fluoroscopic image. According to manufacturer instructions, 'kV dose' was the value at which the dose was switched over for dose reduction. Dose reduction would be performed at a preselected kV.

For image parameters, edge enhancement was increased from 15% to 20%. It resulted in a clearer display of contrast differences (e.g., outline of biliary tree). However, this also caused more noise. The iNoise reduction setting (Artis zee multi-purpose system) compensated for increased noise. If the dose is reduced, additional noise will be perceived as poor image quality. To compensate for the increased image noise, the acquisition program can be configured to adjust the edge enhancement value. DDO-Kernel refers to digital density optimisation Kernel. DDO (harmonisation) reduces the dynamic range of an image (bright areas are less bright, dark areas are less dark). By reducing the dynamic range, this allowed us to increase the contrast without saturation of the image in bright or dark areas. According to manufacturer instructions, K-factor was based on averaging over time. Reduction of image noise could be achieved by weighted averaging by the

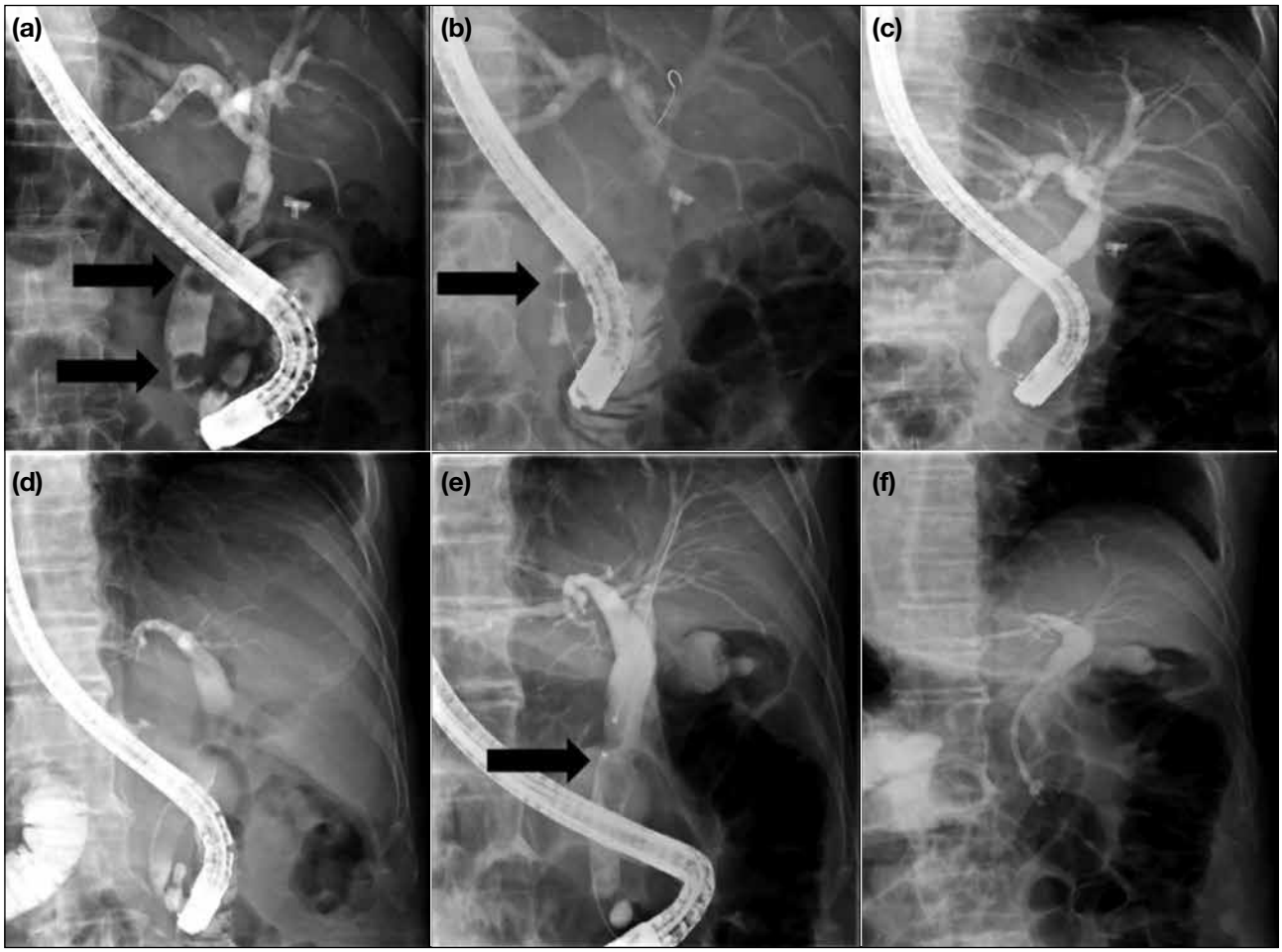

Figure 3. (a-c) A 69-year-old man, body weight 63 kg, with history of cholecystectomy and recurrent common bile duct stones, underwent follow-up ERCP in standard-dose setting. Common duct stone removal (arrows in a) was performed with stone extraction balloon (arrow in b). Fluoroscopy time: 7.5 minutes; DAP: 13.5 Gycm^2. (d-f) A 85-year-old man, body weight 64 kg, with history of recurrent cholangitis, had follow-up ERCP with the low-dose settings. Common duct stone removal (arrow in e) was performed with a mechanical lithotripter basket. Fluoroscopy time: 9.5 minutes; DAP: 10.4 Gycm^2. Note the comparable radiographic image quality between standard (a-c) and low-dose settings (d-f).
Abbreviations: DAP = dose area product; ERCP = endoscopic retrograde cholangiopancreatography.

Table 6. Comparison of image quality variables.

Variables	Total (n = 50)	Standard ERCP setting (n = 25)	Low-dose ERCP setting (n = 25)	p Value
Modified image quality criteria score by radiologist A†				1.0*
Score 3	42 (84%)	21 (84%)	21 (84%)	
Score 2	8 (16%)	4 (16%)	4 (16%)	
Modified image quality criteria score by radiologist B†				0.189*
Score 3	44 (88%)	20 (80%)	24 (96%)	
Score 2	6 (12%)	5 (20%)	1 (4%)	
Subjective image quality score by radiologist A‡				1.0*
3 - Good quality	14 (28%)	7 (28%)	7 (28%)	
4 - Excellent quality	36 (72%)	18 (72%)	18 (72%)	
Subjective image quality score by radiologist B‡				1.0*
3 - Good quality	9 (18%)	4 (16%)	5 (20%)	
4 - Excellent quality	41 (82%)	21 (84%)	20 (80%)	

Abbreviation: ERCP = endoscopic retrograde cholangiopancreatography.
* Chi-square test.
† Inter-observer agreement of modified image quality criteria score between radiologist A and B: measurement of agreement by Kappa statistics = 0.669.
‡ Inter-observer agreement of subjective image quality score between radiologist A and B: measurement of agreement by Kappa statistics = 0.722.

factor $\sqrt{(2k-1)}$. However, noise reduction by averaging may result in reduced contrast and 'ghost images' of fast-moving objects. The K-factor influences the noise impression of the image. A high K-factor means less, and a low K-factor, more image noise. If high K-factors were used, lag effects (in which the image becomes blurred due to patient's movement) appeared in the image.

The fluoroscopic machine uses various copper filters. These filter out the low-energy components of the X-ray spectrum that are not needed to create the image. This causes hardening of the beam, reducing not only the skin dose to the patient but also the scattered radiation to not only endoscopist, but also other staff in the room. The copper filters were from 0.2 to 0.6 mm thickness in our setting.

A reduced pulse rate would help reduce the radiation load on the patient and other personnel, but it would require endoscopists' adjustment. It was kept constant at 7.5 fps in our study. Perhaps the most readily reliable method of reducing radiation exposure is the reduction of the fluoroscopy time. However, a very complex combination of patient-, endoscopist-, and procedure-related factors contribute to determine the final fluoroscopy time.

Several limitations have to be addressed in this study. First, there are no well-validated objective quality criteria for ERCP radiographic images, rendering the assessment of image quality not standardised. The proposed modified quality criteria adopted from European guidelines[6] may not necessarily be truly representative of objective image quality. Further study is warranted to establish quality criteria for ERCP radiographic images so that the diagnostic quality can be better assessed under a standardised approach. Second, the use of a dedicated fluoroscopic machine (Artis zee multi-purpose system) may render the results not generalisable. The radiographic techniques and acquisition parameters in models from various manufacturers differ. Every effort should be made to ensure good radiographic techniques and to tailor specific examinations to the indication, patient and user, in an attempt to achieve the ALARA principle. Third, use of thermoluminescent dosimeters may better reflect the effective dose to patients, endoscopists, and assistants. Fourth, several potential confounding factors were not recorded and controlled for, including endoscopists' experience, trainee involvement, specific ERCP procedures (such as pre-cut sphincterotomy or hilar stent placement), and patient positioning.[9] However, we believed there was a high probability that the low-dose setting in our machine could still offer substantial radiation dose reduction, after the above-named covariates being adjusted for.

CONCLUSION

Our study devised a simple practical dose reduction method by adjusting the acquisition parameters on the fluoroscopy machine during ERCP, without lengthening the fluoroscopy time or significant compromising image quality and outcome of ERCP.

REFERENCES

1. Chen MY, Van Swearingen FL, Mitchell R, Ott DJ. Radiation exposure during ERCP: effect of a protective shield. Gastrointest Endosc. 1996;43:1-5.
2. Kim YJ, Cho KB, Kim ES, Park KS, Jang BK, Chung WJ, et al. Efficacy of a self-designed protective lead shield in reduction of radiation exposure dose during endoscopic retrograde cholangiopancreatography [in Korean]. Korean J Gastroenterol. 2011;57:28-33.
3. Muniraj T, Aslanian HR, Laine L, Farrell J, Ciarleglio MM, Deng Y, et al. A double-blind, randomized, sham-controlled trial of the effect of a radiation-attenuating drape on radiation exposure to endoscopy staff during ERCP. Am J Gastroenterol. 2015;110:690-6.
4. Hart D, Hillier MC, Shrimpton PC. Doses to patients from radiographic and fluoroscopic X-ray imaging procedures in the UK — 2010 review. Health Protection Agency, Centre for Radiation, Chemical and Environment Hazards; June 2012.
5. Dumonceau JM, Garcia-Fernandez FJ, Verdun FR, Carinou E, Donadille L, Damilakis J, et al. Radiation protection in digestive endoscopy: European Society of Digestive Endoscopy (ESGE) guideline. Endoscopy 2012;44:408-24.
6. Johanson JF, Cooper G, Eisen GM, Freeman M, Goldstein JL, Jensen DM, et al. Quality assessment of ERCP. Endoscopic retrograde cholangiopancreatography. Gastrointest Endosc. 2002;56:165-9.
7. European Commission. European Guidelines on Quality Criteria for Diagnostic Radiographic Images. Luxembourg: European Commission; 1996.
8. Heyd RL, Kopecky KK, Sherman S, Lehman GA, Stockberger SM. Radiation exposure to patients and personnel during interventional ERCP at a teaching institution. Gastrointest Endosc. 1996;44:287-92.
9. Jorgensen JE, Rubenstein JH, Goodsitt MM, Elta GH. Radiation doses to ERCP patients are significantly lower with experienced endoscopists. Gastrointest Endosc. 2010;72:58-65.