Thieme

Analysis of Patients' X-ray Exposure in 146 Percutaneous Radiologic Gastrostomies

Analyse der Strahlenexposition für Patienten bei 146 Perkutanen Radiologischen Gastrostomien

Authors
Tim-Ole Petersen, Martin Reinhardt, Jochen Fuchs, Dieter Gosch, Alexey Surov, Patrick Stumpp, Thomas Kahn, Michael Moche

Affiliation
Department of Diagnostic and Interventional Radiology, University Hospital Leipzig, Germany

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Correspondence
Tim-Ole Petersen
Klinik und Poliklinik für Diagnostische und Interventionelle Radiologie, Universitätsklinikum Leipzig, Liebigstraße 20, 04103 Leipzig, Germany
Tel.: ++ 49/3 41/9 71 69 83
Fax: ++ 49/3 41/9 71 74 49
tim-ole.petersen@medizin.uni-leipzig.de

ABSTRACT

Purpose Analysis of patient´s X-ray exposure during percutaneous radiologic gastrostomies (PRG) in a larger population.
Materials and Methods Data of primary successful PRG-procedures, performed between 2004 and 2015 in 146 patients, were analyzed regarding the exposition to X-ray. Dose-area-product (DAP), dose-length-product (DLP) respectively, and fluoroscopy time (FT) were correlated with the used x-ray systems (Flatpanel Detector (FD) vs. Image Itensifier (BV)) and the necessity for periprocedural placement of a nasogastric tube. Additionally, the effective X-ray dose for PRG placement using fluoroscopy (DL), computed tomography (CT), and cone beam CT (CBCT) was estimated using a conversion factor.
Results The median DFP of PRG-placements under fluoroscopy was 163 cGy*cm^2 (flat panel detector systems: 155 cGy*cm^2; X-ray image intensifier: 175 cGy*cm^2). The median DLZ was 2.2 min. Intraprocedural placement of a naso- or orogastric probe (n = 68) resulted in a significant prolongation of the median DLZ to 2.5 min versus 2 min in patients with an already existing probe. In addition, dose values were analyzed in smaller samples of patients in which the PRG was placed under CBCT (n = 7, median DFP = 2635 cGy*cm^2), or using CT (n = 4, median DLP = 657 mGy*cm). Estimates of the median DFP and DLP showed effective doses of 0.3 mSv for DL-assisted placements (flat panel detector 0.3 mSv, X-ray image converter 0.4 mSv), 7.9 mSv using a CBCT – flat detector, and 9.9 mSv using CT. This corresponds to a factor 26 of DL versus CBCT, or a factor 33 of DL versus CT.
Conclusion In order to minimize X-ray exposure during PRG-procedures for patients and staff, fluoroscopically-guided interventions should employ flat detector systems with short transmittance sequences in low dose mode and with slow image frequency. Series recordings can be dispensed with. The intraprocedural placement of a naso- or orogastric probe significantly extends FT, but has little effect on the overall dose of the intervention. Due to the significantly higher X-ray exposure, the use of a CBCT as well as PRG-placements using CT should be limited to clinically absolutely necessary exceptions with strict indication.

Key Points

- Fluoroscopically-guided PRG placements are interventions with low X-ray exposure.
- X-ray exposure from fluoroscopy is lower using flat panel detector systems as compared to image intensifier systems.
- The concomitant placement of an oro- or nasogastric probe extends the fluoroscopy time.
- Gastric probe placement is worthwhile to prevent the premature use of the significantly radiation-intensive CT.
- The use of the C-arm CT or the CT increases the beam exposure by 26 or 33 times, respectively.
- The PRG placement using C-arm CT and CT should only be performed in exceptional cases.

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ZUSAMMENFASSUNG

Ziel Bestimmung der Strahlenexposition für die Patienten bei der Anlage einer Perkutanen Radiologischen Gastrostomie (PRG) in einem größeren Patientenkollektiv.

Material und Methoden Von 146 erfolgreich durchgeführten, konsekutiven, primären PRG-Anlagen in den Jahren 2004 – 2015 wurden Daten zur Strahlenexposition erhoben. Dabei wurden die Parameter Dosisflächenprodukt (DAP), respektive Dosislängenprodukt (DLP) und die Durchleuchtungszeit (FT) erfasst und in Bezug auf die verwendeten Geräte (Flachdetektor (FD) vs. Bildverstärker (BV)), sowie die Notwendigkeit der periprozeduralen Anlage einer für die Magendistension notwendigen naso- oder orogastralen Sonde hin analysiert. Ergänzend wurde die effektive Dosis von PRG-Anlagen mittels Röntgendurchleuchtung (DL), Computertomografie (CT) und Interventionen mit C-Bogen-CT (CBCT) mit dem entsprechenden Konversionsfaktor bestimmt.

Ergebnisse Das mediane DFP von PRG-Anlagen unter DL lag bei 163 cGy*cm² (FD: 155 cGy*cm²; BV: 175 cGy*cm²). Die mediane DLZ betrug 2,2 min. Dabei führte eine intraprozedurale Anlage einer naso- oder orogastralen Sonde (n = 68) zu einer signifikanten Verlängerung der medianen DLZ auf 2,5 min gegenüber 2 min bei Patienten mit bereits liegender Sonde. Zusätzlich wurden Dosiswerte von kleineren Patientengruppen analysiert, bei denen die PRG CBCT-gestützt (n = 7; medianes DFP = 2635 cGy*cm²), oder CT-gestützt (n = 4, medianes DLP = 657 mGy*cm) angelegt wurde. Durch Abschätzungen aus den medianen DFP bzw. DLP ergaben sich effektive Dosen von 0,3 mSv für DL-gestützte Anlagen (FD 0,3 mSv; BV 0,4 mSv), mittels FD mit CBCT 7,9 mSv, und bei PRG-Anlagen im CT eine effektive Dosis von 9,9 mSv. Das entspricht einem Faktor 26 von DL gegenüber CBCT, beziehungsweise einem Faktor 33 von DL gegenüber CT.

Schlussfolgerung Perkutane Radiologische Gastrostomien unter DL sind Interventionen mit geringer Röntgenstrahlenexposition. Die intraprozedurale Anlage einer naso- oder orogastralen Sonde verlängert die Durchleuchtungszeit, hat aber nur einen geringen Einfluss auf die Gesamtdosis der Intervention. Um die Strahlenexposition bei PRG-Anlagen für Patienten und Personal zu minimieren, sollte bei fluoroskopisch geführten Interventionen ein Flachdetektorsystem mit kurzen Durchleuchtungssequenzen in niedriger Dosis und geringer Bildfrequenz genutzt werden. Aufgrund der deutlich höheren Strahlenexposition sollten sowohl der Einsatz einer C-Bogen-CT als auch PRG-Anlagen im CT auf klinisch unbedingt notwendige Ausnahmen mit strenger Indikationsstellung beschränkt werden.

Introduction

Percutaneous radiological gastrostomy (PRG) is a safe procedure and is an established alternative to percutaneous endoscopic gastrostomy (PEG) as a means to provide access for enteral feeding. Unlike PEG, PRG has to be performed using image guidance and a nasogastric tube by means of gastric insufflation. Since its initial description in 1981 [1] PRG is generally performed using X-ray fluoroscopy [2]. Alternate or complementary imaging procedures for guiding the intervention are sonography, cone beam computed tomography (CBCT), or computed tomography (CT). If there is blockage into the stomach, placement of the nasogastric tube can be more difficult, and may then also be performed under image guidance.

Published data on PRG indicate a high success rate with few complications [3 – 7]. However, there are very few publications that discuss radiation exposure to patients. Radiation exposure during PRG interventions has not yet been systematically investigated in a larger cohort. Only three publications with significantly smaller cohorts (n = 9 – 106) identify the dose area product (DAP; 296 – 4615.8 cGy*cm²) [8 – 10]. The fluoroscopy time is stated by only five authors (2.1 – 12.6 min) [3, 9 – 12]. Only in the case of one study is the patient cohort larger than the cohort presented here [3]. To date there has been no investigation into the relationship between DAP and fluoroscopy time on the intraprocedural placement of an orally or nasally inserted nasogastric tube (NGT) or the detector type used.

The aim of this study, therefore, was to determine radiation exposure during PRG procedures using DAP and fluoroscopy time in a larger patient cohort as well as research the influence of the nasogastric tube and detector type. In addition, by determining the effective dose, a comparison between fluoroscopy, CT or CBCT should be possible.

Materials and Methods

The radiology information system (RIS) was used to perform retrospective research on successful PRG placements as well as an assessment of radiation exposure values – fluoroscopy time (FT), dose area product (DAP), and dose length product (DLP) for fluoroscopy and CT-guided PRG placements from 2004 to 2015. In addition, the detector systems used by the fluoroscopy systems, the use of special technologies (for example, CBCT) and the necessity of intraprocedural placement of a nasogastric tube were documented. Additional clinical information was obtained from the hospital information system.

Of 214 documented PRGs in the RIS, 68 records were incomplete, thus, 146 records of successful PRG placements could be evaluated. The gender distribution was 4.4:1 (m:w) and the mean age was 62.1 years (▶ **Table 1**).

Primarily tumor patients (90 %) were treated; due to hospital referral preferences, most patients (n = 122; 83 %) had head and neck malignancies. In patients referred from the ear neck throat (ENT) clinic, PEG trials were either unsuccessful, or endoscopy was not considered possible or the risk of an injury after oropharyngeal reconstruction was considered too high. The next largest patient group had mediastinal malignancies (esophageal, bron-

▶ **Table 1** Demographic data and patient characteristics.

Parameter	Value
primary successful PRG placements	146
gender	119 male
	27 female
age	62.1 years (SD ± 8.2; Min. 42, Max. 86)
primary disease	132 (90 %) malignancies
	122 (83 %) head-neck malignancies
	10 (7 %) other malignancies
	6 (4 %) benign stenosis or similar
	6 (4 %) neurological primary disease
	1 (1 %) Boerhaave syndrome
	1 (1 %) ARDS

PRG = percutaneous radiological gastrostomy, SD = standard deviation, ARDS = Adult Respiratory Distress Syndrome.

chial, thyroid, and lymph node metastases, [n = 10; 7 %]), followed by benign changes such as esophageal stenosis (n = 6; 4 %) and other primary diseases (n = 2; 2 %) (▶ **Table 1**).

The group of neurological diseases (n = 6, 4 %; 3 cases of apoplexy; 1 case of intracerebral hemorrhage; 1 centronuclear myopathy; 1 case of multiple sclerosis) is clearly underrepresented in our patient cohort compared to other publications on PRG [13 – 15].

142 PRGs were performed in a known technique under fluoroscopy [1]. First, upper abdominal sonography was performed to mark the hepatic border. After placement of a nasogastric tube, the stomach was distended with ambient air [2, 3, 16], and extensive local anesthesia was performed from the cutis to the frontal wall of the stomach. Two gastropexies applied diametrically around the gastrostomy itself prevent diversion of the stomach during dilatation of the pathway. After puncture and dilatation, the gastrostomy probe is inserted centrally between the gastropexies using the Seldinger technique. Each puncture was performed with a suction-applied syringe and fluoroscopy. Documentation of the intragastric position was made by contrast injection via the puncture needle or via the PRG in the final tubogram.

Of the 142 PRGs placed using fluoroscopy, 97 were performed on flat panel detector systems (FD, Innova 4100, GE Healthcare, Milwaukee, USA (n = 91)) using a 41 × 41 cm detector or Axiom Artis dMP (Siemens, Erlangen (n = 6)) with a 30 × 38 cm detector. Alternatively (n = 38) the PA plane of a two-plane angiography system with image intensifier (II) (Axiom Artis BA, Siemens, Erlangen) with a 40 cm detector diameter.

Each procedure was performed using a low-dose fluoroscopy mode (tube voltage 80 kV, tube current 7.5 mA and 0.1 mm Cu filter) with a standard image frequency of 15 images/sec. Diagnostic series were used in all cases for documentation (2 images/sec, 100 kV, 290 mA). In 7 cases, a CBCT with a rotational speed of 40°/sec was also employed (only available on the Innova 4100).

The CT-guided PRG placements (n = 4) used a 16-slice CT (Brilliance Big Bore, Philips, Cleveland, USA). Spiral CT slices were reconstructed for planning and final control (2 or 3 mm, collimation 16 × 1.5 mm, pitch 0.938, rotation time 0.75 sec, FOV 350 mm, 120 kV with automatic dose modulation). Punctures were made with sequential CT fluoroscopy (4 × 3 mm, 120 kV, 65 mA, FOV 500 mm).

The dose values were taken from the patient documentation in the RIS, and the dose values were displayed on the examination equipment.

All procedures were conducted or supervised by specialists with 30, 14, 6 and 6 years of experience in interventional radiology.

The effective dose was estimated for better comparability of radiation exposure in different modalities. This is an estimated value with only limited accuracy due to the heterogeneity of the radiation sensitivity of the patient's organs as well as partial exposure as a result of accurate collimation. Additional influencing variables include beam quality (tube voltage and filter used), projection direction and radiation field geometry [17].

On the day before the procedure, the patients and/or caregivers were informed about the procedure and gave their written consent. The evaluation was approved by the local ethics committee.

Non-parametric Wilcoxon tests were used to test differences between the groups due to the skewed distribution of the variables. Normally-distributed variables (age) were given with mean value, standard deviation as well as minimum and maximum value. Skewed values (fluoroscopy time, DAP) were indicated as median, mean as well as minimum and maximum value. The advantage of the median compared to the mean value lies in the stability with respect to extreme values, therefore the median is preferably identified in the subsequent text. Fluoroscopy time was indicated in decimal parts of a minute.

Results

The median DAP of the 142 fluoroscopically placed PRGs was 163 cGy*cm² (▶ **Table 2**). The median DAP of the FD group was 155 cGy*cm², on the image intensifier 175 cGy*cm². The median fluoroscopy time was 2.2 minutes (▶ **Table 3**).

In 68 patients the nasogastric tube was placed peri-interventionally; in the remaining 67, it was placed on the ward. Of the patients receiving a nasogastric tube, 94.5 % had malignancies in the mouth, neck or mediastinum which made probing difficult. A nasogastric tube had to be inserted in 55 % of PRG placements on the flat panel detector; during interventions on the image intensifier, only 39 % required this. For fluoroscopically-guided nasogastric placements the median DAP was 162 cGy*cm², and the fluoroscopy time was 2.5 minutes. For patients with an existing nasogastric tube, the median DAP was 178 cGy*cm² and the median fluoroscopy time was 2 minutes (▶ **Table 2, 3**).

▶ **Table 2** Dose area product (DAP) depending on the systems used, the use of Cone Beam CT (CBCT) and the need for periprocedural placement of a nasogastric tube (NGT). Dose length product (DLP) in CT-guided gastrostomies.

DAP (cGy*cm²)	n	median	average	minimum	maximum	SD
total under fluoroscopy	142	163	296	10	1754	± 330.1
flat panel detector	97	155	295.9	10	1754	± 365
image intensifier	38	175	296.3	34	896	± 241.9
flat panel detector with CBCT	7	2635	2547.1	911	4761	
PRG with placement of a NGT	68	162	306.4	10	1754	± 362.9
flat panel detector	53	162	307.5	10.0	1754	
image intensifier	15	157	302.6	58.4	896	
PRG without placement of a NGT	67	178	284.6	16	1467	± 293.7
flat panel detector	44	148	279.0	16	1467	
image intensifier	23	268	292.6	34	648	
CT (DLP in mGy*cm)	4	657	679	427	974	

DAP = Dose area product in cGy*cm², NGT = nasogastric tube, DLP = dose length product in mGy*cm, SD = standard deviation, PRG = percutaneous radiological gastrostomy, DL = fluoroscopy, CT = computed tomography, CBCT = cone beam CT. All comparable median values have only a low significance ($p > 0.05$).

▶ **Table 3** Fluoroscopy time (FT) depending on the systems used, the use of Cone Beam CT (CBCT) and the need for a periprocedural placement of a nasogastric tube (NGT).

fluoroscopy time values (minutes)	median	average	minimum	maximum	SD
total	2.2	3.1	0.4	20	± 3
flat panel detector	2.5*d	3.4	0.4	20.0	± 3.5
image intensifier	1.3*d	2.0	0.4	18.0	± 2.9
PRG with placement of a NGT	2.5**a	3.8	0.5	20	± 3.8
flat panel detector	3.1**c	4.2	0.5	20.0	
image intensifier	1.4**c	2.7	0.5	18.0	
PRG without placement of a NGT	2**a	2.3	0.4	6	± 1.3
flat panel detector	2.2***b	2.7	0.4	6.0	
image intensifier	1.5***b	1.3	0.4	3.9	
using CBCT	4.7	5.2	2	10.24	

FT = Fluoroscopy time in minutes (decimal places after period), NGT = nasogastric tube, SD = standard deviation, PRG = percutaneous radiological gastrostomy, CT = computed tomography, CBCT = cone beam CT. * $p > 0.05$, ** $p < 0.05$, *** $p < 0.001$, **** $p \leq 0.00001$, dependent variables indicated with small letters.

The effective dose was estimated as a function of the placement parameters [17]. A conversion factor of approximately 0.2 mSv/mGy*cm² yielded an estimated median effective dose of approximately 0.3 mSv for all PRGs placed under fluoroscopy (▶ **Table 4**).

In the case of 7 procedures an additional CBCT was necessary for the following reasons: to avoid puncturing structures in the access path (2), to rule out penetration of adjoining structures after puncturing the stomach (3), and after placing the PRG (3) to check the proper position of the feeding tube. In 5 of the 7 procedures a Billroth II procedure was an issue.

The median DAP was 2635 cGy*cm² when CBCT was employed. The median fluoroscopy time for these patients was 4.7 minutes. At a conversion factor of 0.3 mSv/mGy*cm² [18], the estimated median effective dose was approximately 7.9 mSv (▶ **Table 4**).

Four gastrostomies were primarily performed using CT. The reasons for this were rejection of a nasogastric tube by the patient

▶ **Table 4** Estimated effective dose in procedures with fluoroscopic, Cone Beam CT or CT-guidance.

	DAP (cGy*cm²)		effective dose (mSv)	
	median	average	median	average
fluoroscopy total	163	296	0.3	0.6
flat panel detector	155	295.9	0.3	0.6
image intensifier	175	296.3	0.4	0.6
flat detector with CBCT	2635	2547.1	7.9	7.6
CT (DLP in mGy*cm)	657	679	9.9	10.2

[+] conversion factors for fluoroscopy 0.2 mSv/mGy*cm²; CBCT 0.3 mSv/mGy*cm²; CT 0.015 mSv/mGy*cm. DAP = Dose area product in cGy*cm², DLP = dose length product in mGy*cm, PRG = percutaneous radiological gastrostomy, CT = computed tomography, CBCT = cone beam CT.

▶ **Table 5** Comparison of published fluoroscopy time (FT) with present data.

author	procedures	median FT	average FT	min. – max.	SD
Kloeckner R et al. [17]	n = 53		5.9		± 5.3
Mildenberger P et al. [20]	n = 90		12.6	1.2 – 81	
Thornton FJ et al. [21]	n = 90	4.7 – 4.6			± 2.4 / 2.3
Perona F et al. [4]	n = 254		2.1	2.1 – 9	
Baumann F. et al [20]	n = 9		5.6/7.6		
Own cohort	n = 146	2.2	3.1	0.4 – 20	± 3

FT = Fluoroscopy time in minutes (decimal places after period), SD = standard deviation. Thornton et al. do not indicate whether their data reflects median or average fluoroscopy time. The two values stand for "with" or "without" gastropexy, Baumann et al.: fluoroscopy time before and after unblinding with real time dosimetry.

(1); technically unsuccessful placement (1); esophageal resection due to Boerhaave syndrome with cervical perforation (1); mediastinal tumor cavity with esophagotracheal fistula (1) and an interposed colon with narrow puncture access (1). The median dose length product (DLP) war 657 mGy*cm. With a conversion factor of 0.015 mSv/mGy*cm [19], the estimated median effective dose was 9.9 mSv.

Discussion

Evaluation of patient radiation exposure during PRG placement shows significant differences with respect to the imaging procedure. PRG placements under fluoroscopy are quick and require the least amount of radiation. If CBCT is required, radiation exposure to a patient increases 26-fold. Performing the procedure using CT further increases the radiation dose. The necessity of placing the nasogastric tube using fluoroscopy increases the fluoroscopy time significantly for the patient.

Clinically, PEG and PRG have long been primary procedures compared to surgical gastrostomy. For years publications about PRG have shown a very high success rate of 96 – 100 %, with only approx. 1.3 – 7.3 % major complications and 4.4 – 46.8 % minor complications [3 – 7].

Median DAP during a PRG procedure was relatively low, 163 cGy*cm². Concurring with earlier publications, this was dependent on the type of detector used, so using a flat panel detector the dose was lower compared to the use of an image intensifier, at the same image quality [20]. The possible influence of different field and zoom intensities cannot be determined retrospectively.

To date there are only three publications, each with smaller cohorts compared to the study at hand, patient cohorts (▶ **Table 6**) which state the DAP during PRG placements. A registry analysis of 17 centers [8] with 106 data sets described a median DAP of 430 cGy*cm². Kloeckner et al. [9] report a median DAP of 3260 cGy*cm². Baumann et al. investigated the influence of real time dosimetry on the level of radiation exposure among other things during 9 gastrostomies. They estimate the mean DFP with direct dose feedback at 4284 cGy*cm², while the initial value prior to visible real time dosimetry was 7274 cGy*cm² [10]. At 163 cGy*cm², our median DAP is lower by a factor of 2.6, respectively a factor of 20; the mean value 296 cGy*cm² is lower by factors of 5.8, 14.9 and 15.6, respectively. The detemined values are thus significantly lower than the data published so far. All PRG

▶ **Table 6** Comparison of published dose-area-product with present data.

author	procedures	median DAP	average DAP	min. – max.	SD
Lowe AS et al. [16]	n = 106	430	954.68	52 – 8840	
Kloeckner R et al. [17]	n = 53	3260	4410		± 4940
Baumann F. et al [18]	n = 9		7274/4284		
Own cohort	n = 146	163	296	10 – 1754	± 330.1

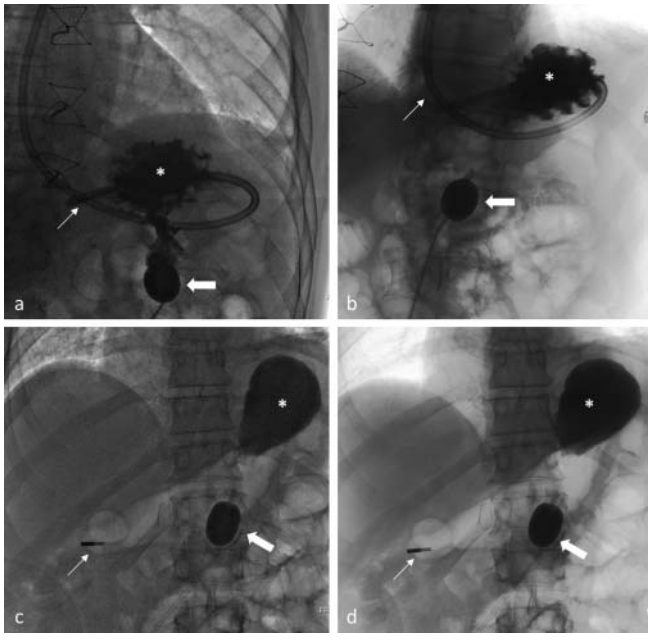
DAP = Dose area product in cGy*cm^2, SD = standard deviation, Baumann et al.: Value before and after unblinding with real time dosimetry.

placements we performed used a reduced dose of fluoroscopy with the most precise collimation possible (▶ **Fig. 1**). Individual steps (such as puncture or the final tubogram) could be documented by storing a fluoroscopic LIH (last image hold), without having to resort to a series of exposure-intensive diagnostic images, without resulting in loss of relevant information (▶ **Fig. 1**).

In contrast to most other publications, our patient cohort includes predominantly those with ENT tumors due to internal clinical referrals. However, this fact does not appear to affect the very high 99 % success rate of the procedure [2]. Due to the high proportion of tumor- or therapy-associated obstacles to passage, in our patient cohort placement of a nasogastric tube represented a particular challenge which could generally only be overcome using X-ray guidance. Placing the tube extended the median fluoroscopy time statistically significantly by 25 % from 2 minutes to 2.5 minutes (▶ **Table 3**). The fact that the DAP did not increase is due to a very low dose of fluoroscopy and to the broad scatter of the image intensifier subgroup values (n = 38). The proportion of periprocedural nasogastric tube placements in the flat panel detector group, at 55 %, higher compared to 39 % in the image intensifier group, which may have resulted in an additional bias with a relative increase of DAP in the flat panel detector group compared to the image intensifier group.

If the larger flat panel detector group (n = 97) is considered in isolation, there is a slight increase of DAP during nasogastric tube placement of only 9 % (n = 44). This increase is almost negligible compared to the significantly higher beam exposure during PRG placements using CT. Therefore, persistent attempts should be made to establish insertion of a nasogastric tube during clinical practice, rather than perform the intervention using CT.

For patients and interventionalists alike, both tube and PRG placement present the challenge of adequate radiation protection. During fluoroscopically-guided nasogastric tube placement, the physician stands directly next to the head of the patient where protection by the radiation protection above and below the table is frequently not provided. During the PRG placement itself, the above-table lead glass pane obscures the view of the puncture site and is frequently considered a hindrance. Both during guidance of the tube and punctures at a steep angle of approx. 60 – 80° to the skin, the hands are frequently close to the patient and can thus reach directly into the beam. In this case, it is imperative to use tools such as needle holders to avoid this direct beam exposure. If manipulation in the direct path of the beam cannot be avoided, the sterile radiation protection glove should be worn.



▶ **Fig. 1** Comparison of image quality between fluorscopy **a, c**) and diagnostic images (**b, d**). Final tubograms after PRG of a 68 year old patient **a, b**); and a 47 year old patient **c, d.** The blocked PRG (fat arrow) is inside the contrast-filled stomach (Asterisk), while the nasogastric tube is still in place (slim arrow).

The very steep angle of puncture prevents positioning the detector close above the patient's body surface which increases the performance of the tubes, thus raising the radiation exposure level (▶ **Fig. 1**). Baumann et al. showed that by using real-time dosimetry, DAP was reduced by more than 41 % after a learning phase [10].

Compared with the literature, the median and mean fluoroscopy time of 2.2 minutes and 3.1 minutes respectively when placing a nasogastric tube was significantly less than published data, with 2.5 and 3.8 minutes respectively (▶ **Table 5**). Kloeckner et al. [9] report a mean fluoroscopy time of 5.9 minutes. In their article Baumann et al. describe how the use of real-time dosimetry [10] allowed an increase of fluoroscopy time from 5.6 to 7.6 minutes with a corresponding reduction of DAP. A possible explanation

for this is the more frequent use of fluoroscopy rather than an image series. Mildenberger et al. [12], in a mixed cohort of 90 percutaneous radiographic gastro- and enterostomies, indicate a mean fluoroscopy time of 12.6 minutes; however, almost 1/3 of these were distinctly complex duodenal or jejunostomies. In a comparison between PRG with and without gastropexy, Thornton et al. [11] reported a fluoroscopy time of 4.73 minutes with gastropexy and 4.59 minutes without the procedure. However, there was no indication of whether these were median or mean values. Perona et al. [3] quantify the mean fluoroscopy time at only 2.12 minutes. However, the mean in this article was based on 254 primary PRG insertions and 275 replacements. The latter are significantly less complex and, according to our own experience, are associated with a significantly shorter procedure and fluoroscopy time. A further difference with our data is the low proportion of periprocedural nasogastric tube placements (5.4 %).

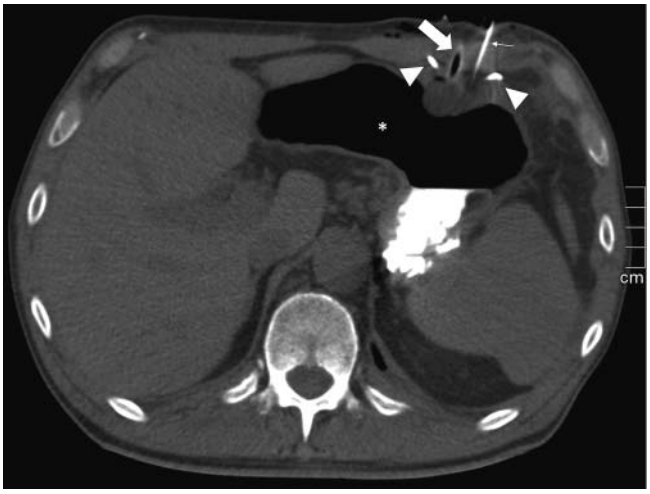
In their article, Kuon et al. [21] demonstrated that radiation exposure can be derived only conditionally from fluoroscopy time, but rather is due to the number and frequency of the dose-intensive serial images. However, this observation is hardly applicable to our cohort since serial images have been avoided as much as possible.

According to Babst et al. CBCT offers new possibilities to display and perform an intervention [22] while increasing safety. In the patient population presented here, CBCT was used to plan access routes more safely or to rule out the possibility of damage to adjacent structures during the intervention. In our patients, median radiation exposure was sixteen times higher compared to conventional fluoroscopy. The doubling of the median fluoroscopy time in this subgroup can be explained by the higher complexity of the interventions requiring the use of CBCT. In their paper, Möhlenbruch et al. report a 100 % success rate during 18 CBCT-supported PRGs [23]. The dose values indicated are 20 % higher than in our cohort.

In our own practice, PRGs are performed only in difficult exceptional cases using sequential CT fluoro (▶ **Fig. 2**). The advantage of non-superimposed imaging compared to fluoroscopy is associated with the disadvantages of a lack of real-time imaging and much higher radiation exposure. The latter would increase significantly in the case of the real-time CT-fluoro, whereby the interventionalist would have his own hands immediately next to or even in the direct beam path with few possible protective measures. De Bucourt et al. calculate the radiation exposure for the radiologist using real-time CT fluoro at 0.6 µSv per 5 s, assuming personal radiation protection clothing and a distance of 50 cm gantry clearance [24]; however no indication is made of the actual required fluoroscopy duration.

In some centers, CT-guided PRG is regularly performed or has superseded fluoroscopy-guided PRG. The published success and complication rates are comparable to fluoroscopy -controlled PRG (CT-guided PRG success rate 95.2 – 97.7 % with 4 – 8.7 % major complications) [24 – 26].

During our CT-guided PRG placements the median DLP was 657 mGy*cm. To date there are no published data regarding radiation exposure for CT-guided PRG. With only four patients our subgroup can only show a tendency. In this case, evaluations of larger patient cohorts in the course of further studies are needed.



▶ **Fig. 2** The final CT-scan shows the blocked PRG (fat arrow) in a 55 year old patient, the two gastropexy-anchors (arrow heads) and the 22 G cannula (slim arrow) for air injection to inflate the stomach (Asterisk).

In one patient, insertion of a nasogastric tube was not possible despite lengthy attempts due to a multistage nasopharyngial tumor. Good sonographic visibility of the stomach allowed performance of a sonographically supported direct puncture. This technique had been described earlier [27, 28] and allows PRG to be performed at the patient's bed, for example in the ICU. The literature also describes position control [29] or entire gastrostomy tube replacement using only sonographic guidance [30]. However, since the visibility of materials used is limited sonographically, and since one hand of the interventionalist is needed to hold the transducer, application of this technique is limited to individual cases, such as children.

The imaging methods used can be compared by estimating the effective patient dose based on the median DAP or DLP. For fluoroscopy, median effective doses were estimated at 0.3 mSv (FD 0.3 mSv, image intensifier 0.4 mSv). FD with CBCT resulted in 7.9 mSv and 9.9 mSv for PRG placement using CT (▶ **Table 4**). This corresponds to a factor of 26 for fluoroscopy compared to CBCT, a factor of 1.3 for CBCT compared to CT and a factor of 33 for fluoroscopy compared to CT.

Limitations of this work are the retrospective evaluation of the data and low patient numbers in the subgroups. It was not documented in detail whether the procedure was carried out partially or completely by the experienced specialist or whether this physician supervised a resident physician in the 4th or 5th year of training. Duration of the procedure and number of diagnostic series were not documented. A further limitation is that the determined dose values are read-out values according to the device dosage protocol, and direct dosimetry was not performed. The referring physicians provide a preselection of patients which makes it difficult in our case to assess technical success.

CLINICAL RELEVANCE

Fluoroscopically-guided percutaneous radiological gastrostomy is a fast and safe procedure with low radiation exposure to the patient. Radiation exposure can be further reduced without loss of quality through precise collimation, short fluoroscopy time with a low dose and limited image frequency as well as dispensing with serial images. Even in case of difficult anatomical features the nasogastric tube can be inserted with limited additional radiation exposure in the same procedure using fluoroscopy. Noncritical use of CBCT or CT should be dispensed with at a significantly higher effective dose.

Conflict of Interest

The authors declare that they have no conflict of interest.

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