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

Analyse der Strahlenexposition für Patienten bei 146 Perkutanen Radiologischen Gastrostomien

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Key words
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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 Intensifier (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*cm2 (flat panel detector systems: 155 cGy*cm2; X-ray image intensifier: 175 cGy*cm2). 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*cm2), 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 inappradural 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.

Citation Format
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-
Our patient cohort compared to other publications on PRG [13] is clearly underrepresented in pathy; 1 case of multiple sclerosis) is clearly underrepresented in our patient cohort compared to other publications on PRG [13].

Of the 142 PRGs placed using fluoroscopy, 97 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 extension of 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 wall of the stomach. Two gastropexies applied diametrically around the gastrostomy itself prevent diversion of the stomach. Two gastropexies applied diametrically around the gastrostomy itself prevent diversion of the stomach wall.

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. 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 1 Demographic data and patient characteristics.

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

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

### 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).
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...
(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) was 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 determined values are thus significantly lower than the data published so far. All PRG

| 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*cm². 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 et al. [17]          | n = 53      | 5.9         | ±5.3         |               |
| Mildenberger et al. [20]       | n = 90      | 12.6        | 1.2 – 81     | ±2.4 / 2.3   |
| Thornton et al. [21]           | n = 90      | 4.7 – 4.6   | 2.1 – 9      |               |
| Perona et al. [4]              | n = 254     | 2.1         | 2.1 – 9      |               |
| Baumann 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.
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.

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 [10] allowed an increase of fluoroscopy time from 5.6 to 7.6 minutes with a corresponding reduction of DAP. A possible explanation

<table>
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<th>author</th>
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<th>median DAP</th>
<th>average DAP</th>
<th>min. – max.</th>
<th>SD</th>
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<td>Kloeckner R et al.</td>
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<td>4410</td>
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<tr>
<td>Baumann F. et al</td>
<td>n = 9</td>
<td>163</td>
<td>7274/4284</td>
<td>10 – 1754</td>
<td>± 330.1</td>
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<tr>
<td>Own cohort</td>
<td>n = 146</td>
<td>296</td>
<td>163</td>
<td>10 – 1754</td>
<td>± 330.1</td>
</tr>
</tbody>
</table>

DAP = Dose area product in cGy cm², SD = standard deviation, Baumann et al.: Value before and after unblinding with real time dosimetry.

Fig. 1 Comparison of image quality between fluoroscopy 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).
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 fluoroscopy (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 mGycm. 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.

In one patient, insertion of a nasogastric tube was not possible despite lengthy attempts due to a multistage nasopharyngeal 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.

**References**


