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# Determinants of Image Retakes in General Digital Radiography

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## Abstract

*Although it has replaced screen-film radiography in various radiological units, digital radiography (DR) still produces high image retake, which contributes unnecessary radiation dose to patients. This study aimed to investigate patient- and radiographer-related determinants of image retakes in general DR among hospitals in Southeastern Philippines. A total of 455 images were included in the analysis. Frequency, chi-square test of independence and binary logistics regression were applied. In the adjusted model, image retake occurred more likely in non-sthenic patients compared with sthenic patients (OR = 95.16; 95% CI = 87.42-119.90), in non-ambulatory patients compared with ambulatory patients (OR = 175.59; 95% CI = 143.45-191.80), and in procedures involving the axial section of the body as compared with the appendicular part of the body (OR = 1060.96; 95% CI = 997.68-1175.92). No significant association was observed for patient and radiographers' sexes. The results of this study highlighted that among the variables, procedures that involved asthenic and non-ambulatory patients as well as axial body parts were determinants of image retake occurrence. Intervention programs for image retake prevention in hospitals should put emphasis on these types of patients and radiographic procedures*.

***Keywords****:* determinants, image retake, general digital radiography, Philippines

## 1. Introduction

During the past years, digital radiography (DR) has replaced screen-film radiography in various radiological units. This radiographic technique offers many advantages including ease of use, fast image processing times, and ability to select a dynamic range of exposure and store images for future review without losing quality (Drost, 2011; Don *et al*., 2013; Lança and Silva, 2013; Mothiram *et al.*, 2014). With the advent of this technology, the problem of image retake was gradually eliminated. Significant reduction of retake rates was reported in United Kingdom, Australia, and United States (Foos *et al*., 2009; Waaler and Hofmann, 2010; Weatherburn *et al.*, 2014). Despite these reports, some studies described retake rates in digital radiological units still as high as 5% and even higher (Jones *et al.*, 2011; Andersen *et al*., 2012; Hofmann *et al.*, 2015).

Image retake is the act of repeating a radiographic procedure after producing a diagnostically unacceptable image. It imposes important challenges within radiological units because it contributes unnecessary radiation dose to patients, causes inconvenience, and indicates suboptimal quality management (Foos *et al*., 2009; Prieto *et al*., 2009; Waaler and Hofmann, 2010; Andersen *et al*., 2012). Hence, there is a need to design effective image retake prevention programs or to develop strategies to prevent image retake that can be incorporated in the quality assurance guidelines of a hospital.

Several factors affecting image retake in digital radiography were previously reported. Most of them are controllable and modifiable, and are associated with patient and radiographer's characteristics. Therefore, it is crucial to identify these factors to prevent image retakes. Previous literature described body habitus and patient's walking status as factors that would limit visualization of important body of interest which might need retake of imaging procedure (Shet *et al.*, 2011; Akhtar *et al.*, 2016). Furthermore, image retakes in digital systems are mainly related to the lack of radiographer's work experience, particularly to proper equipment operations and patient positioning (Waaler and Hofmann, 2010). Data from the previous study showed that radiographic examination performed by male radiographer had 25% lesser chance of causing image retake occurrence as compared with female radiographer (Akhtar *et al.*, 2016).

Currently, there is only one associational study about image retake occurrence and its related factors. Lin *et al*. (2016) have identified sex and age of patients

and type of examination to be strongly associated with image retake frequency. Although existing literature revealed significant association between these factors and image retake, there is still a paucity of research which underscores the strength of the association of these factors to image retake occurrence, especially in general DR. A number of studies have focused on the calculation of image retake rates and analysis of retake causes in DR in order to improve the radiological unit services (Andersen *et al*., 2012; Hofmann *et al*., 2015). However, to the best of the author's knowledge, factors that underlie image retake occurrence in DR are not well understood, especially in the Philippine setting.

In order to propose specific guidelines for reducing image retake rates based on significant determinants, more studies are needed. Therefore, the present study investigated patient- and radiographer-related determinants of image retakes in general DR using logistic regression analysis.

## 2. Methodology

### *2.1 Data Collection*

This study used secondary data sourced out from the Picture Archiving and Communications System (PACS) of general DR in five hospitals in Southeastern Philippines. Hospitals were selected based on the availability of general DR and PACS. The five general DR laboratories have similar DR equipment and accessories. Data included all exposed images from October 2019 to December 2019. An image was analyzed when the following variables were included in the description option: age, sex, body habitus, walking status, type of examination of the patients, and name of the attending radiographer. Among the 1,654 images retrieved from the PACS, only 455 images were analyzed after excluding images with incomplete information. A total of 1,199 retrieved images (72.49%) failed to display the name of the attending radiographer; hence, only 455 images (27.51%) were used for the analysis, which were higher than the recommended sample size of 209 calculated using Raosoft sample size calculator with 5% margin of error and 95% confidence level.

The images were further divided into two groups: image retake (246, 54.07%) and diagnostically acceptable image (209, 45.93%) after a thorough evaluation

conducted by two experienced radiographers under the supervision of a board-certified radiologist. An image was considered retake when it has no diagnostic information, has low image quality, and contains artifacts, thereby requiring repetition of radiographic procedure. All radiographer-evaluators have more than five years of clinical experience in DR. The evaluation was conducted in a display monitor under similar conditions of room light and temperature.

The main outcome variable of this study was image retake occurrence. Independent variables included age (in years), sex (male and female), body habitus (sthenic and non-sthenic), walking status (ambulatory and non-ambulatory), and type of examination (axial and appendicular) of patients and age (in years), sex (male and female), and working experience (in years) of performing radiographers. All anonymized patient-related information was directly taken from the image description option. Radiographer-related information were also taken from the human resource department of the hospitals.

*2.2 Data Analysis*

The collected data were entered into Microsoft Excel, and descriptive and inferential statistics were used for analysis. In the descriptive analysis, frequency and percentage were utilized for categorical variables. The image retake rate was determined using Equation 1 (Owusu-Banahene *et al.*, 2014).

$$Image\ retake\ rate\ (\%) = \frac{Number\ of\ retaken\ images}{Number\ of\ examinations} \times 100 \quad (1)$$

In inferential statistics analysis, chi-square test of independence was utilized to determine the association between patient-related factors, as well as RT-related factors, and the occurrence of image retake. After excluding the variables that were not statistically associated with the occurrence of image retakes, binary logistic regression was employed to estimate the odds ratios (ORs) and 95% confidence intervals (CIs) of the significant predictors of general digital radiography image retakes after adjusting for covariates. A P-value of less than 0.05 was considered significant.

## 3. Results and Discussion

Of the 455 images included in the analysis, 246 (54.07%) were image retakes, and 209 (45.93%) were images containing diagnostic information (Table 1). Image retake occurred most frequently in young/middle-aged patients (n = 170, 69.11%), followed by the elderly (*n* = 64, 26.02%) and pediatric patients (*n* = 12, 4.88%). It can be found that female patients (*n* = 186, 75.61%) had higher image retake occurrence than the male patients (*n* = 60, 24.39%). Non-sthenic (*n* = 223, 90.65%) and non-ambulatory (*n* = 233, 94.72%) patients were more prone to image retakes compared to sthenic (*n* = 23, 9.35%) and ambulatory (*n* = 13, 5.28%) patients, respectively. In terms of the type of examination, the procedures involving the axial section of the body accounted for 95.12% (*n* = 234) of the image retakes compared to those involving the appendicular part (*n* = 12, 4.88%).

Table 1. Descriptive and chi-square analyses of the variables and occurrence of image retake

| Variables | | Occurrence of Image Retake | | Chi-Square Test P-value |
|---|---|---|---|---|
| | | Yes (*n* [%]) | No (*n* [%]) | |
| Overall | | 246 (54.07) | 209 (45.93) | |
| Patient's Age (Years) | ≤ 18 | 12 (4.88) | 4 (1.91) | 0.29 |
| | 19-59 | 170 (69.11) | 151 (72.24) | |
| | ≥ 60 | 64 (26.02) | 54 (25.84) | |
| Patient's Sex | Male | 60 (24.39) | 53 (25.36) | 0.03 |
| | Female | 186 (75.61) | 156 (74.64) | |
| Patient's Body Habitus | Sthenic | 23 (9.35) | 74 (35.41) | < 0.001 |
| | Non-sthenic | 223 (90.65) | 135 (64.59) | |
| Patient's Walking Status | Ambulatory | 13 (5.28) | 83 (39.71) | < 0.001 |
| | Non-Ambulatory | 233 (94.72) | 126 (60.29) | |
| Type of Examination | Appendicular | 12 (4.88) | 89 (42.58) | < 0.001 |
| | Axial | 234 (95.12) | 120 (57.42) | |
| Radiographer's Age (Years) | 22-31 | 64 (26.01) | 54 (25.84) | 0.22 |
| | 32-41 | 32 (13.01) | 19 (9.09) | |
| | 42-51 | 150 (60.98) | 136 (65.07) | |
| Radiographer's Sex | Male | 80 (32.52) | 38 (18.18) | < 0.001 |
| | Female | 166 (67.48) | 171 (81.82) | |
| Radiographer's Years of Working Experience | 1-10 | 64 (26.02) | 54 (25.84) | 0.17 |
| | 11-20 | 35 (14.23) | 19 (9.09) | |
| | 21-30 | 147 (59.76) | 136 (65.07) | |

Radiographer aged 22-31 ($n$ = 150, 60.98%) committed the most image retakes compared with radiographer aged 42-51 ($n$ = 64, 26.01%) and 32-41 ($n$ = 32, 13.01%). Male radiographers ($n$ = 166, 67.48%) committed a higher image retake occurrence compared with female radiographers ($n$ = 80, 32.52%). Radiographers with 1-10 years of working experience ($n$ = 147, 59.76%) did the most image retakes compared with radiographers having 11-20 ($n$ = 64, 26.02%) and 21-30 ($n$ = 35, 14.23%) years of experience.

As observed in the analysis, the image retake rate of 54.07% was higher compared with the retake rates of DR observed in United Kingdom (5.5%) (Weatherburn *et al.*, 2014), United States (4.4%-4.9%) (Foos *et al.*, 2009), and Taiwan (4.89%) (Lin *et al.*, 2016). An existing literature reported that an image retake rate of at most 8% is considered acceptable in general DR (Rastegar *et al.*, 2019). Surprisingly, the image retake rate in this investigation was very high and unacceptable. The image retake rate was much higher than the reported retake rate in screen-film radiography (11.4%) (Shalemaei, 2011). Young/middle-aged patients exhibited the highest image retake occurrence compared with elderly and pediatric patients; this result is consistent to the previous literature (Lin *et al.*, 2016). Female patients accounted for a higher occurrence of image retake compared with male patients, contradicting to the investigation conducted by Akhtar *et al.* (2016) and Lin *et al.* (2016). This study showed that non-sthenic and non-ambulatory patients demonstrated a higher image retake occurrence. In practice, non-sthenic and non-ambulatory patients are very difficult to position during radiographic procedures, and thus, are prone to positioning errors (Adler and Carlton, 2013; Bontrager and Lampignano, 2013). These positioning errors were the leading cause of image retake as discovered by Jones *et al.* (2011). Congruent to the findings of the previous studies, the structures in the axial region of the body were reported to account for most of the image retakes in general DR (Foos *et al.*, 2009; Jones *et al.*, 2011).

Similar to the previous report of Akhtar *et al.* (2016), male radiographers demonstrated a higher image retake compared with female radiographers in the investigated hospitals. Possible recommendation for reducing image retake was to provide educational training intervention specific to male radiographers (Akhtar *et al.*, 2016). Consistent with this, the highly experienced radiographers exhibited lower image retake occurrence compared with radiographers with lesser years of working experience.

Presented in Table 1 is the chi-square test P-value between each determinant and occurrence of image retake. The patient's sex, body habitus and walking status; type of examination; and radiographer's sex were significantly associated with the occurrence of image retake ($p < 0.05$). However, the said occurrence was not statistically associated with patient's age, and radiographer's age and years of working experience ($p > 0.05$).

Patient's sex and type of examination were significantly associated with image retake, which is consistent with the investigation conducted by Lin *et al.* (2016). In contrast, patient's age was significantly associated with image retake, which does not agree with one of the key findings of Lin *et al.* (2016).

Binary logistic regression was conducted to determine the significant predictors of image retake occurrence after excluding independent variables that are not statistically associated with the outcome variable (Table 2).

Table 2. Odds ratio and 95% confidence intervals of variables associated with image retake occurrence ($n = 455$)

| Determinants | | Occurrence of Image Retake | | | |
|---|---|---|---|---|---|
| | | B | SE B | OR | 95% CI |
| Patient's Sex | Male | 1 | | | |
| | Female | 0.33 | 0.62 | 1.39 | 0.41-2.71 |
| Patient's Body Habitus | Sthenic | 1 | | | |
| | Non-sthenic | 4.56*** | 0.87 | 95.16 | 87.42-119.90 |
| Patient's Walking Status | Ambulatory | 1 | | | |
| | Non-Ambulatory | 5.17*** | 0.85 | 175.59 | 143.45-191.80 |
| Type of Examination | Appendicular | 1 | | | |
| | Axial | 6.97*** | 1.04 | 1060.96 | 997.68-1175.92 |
| Radiographer's Sex | Male | 1 | | | |
| | Female | 0.56 | 0.66 | 1.75 | 0.48-2.34 |
| Constant | | -8.71*** | 1.34 | <0.001 | |
| $\chi^2$ | | | 546.65 | | |
| *df* | | | 5 | | |

Cox & Snell R Square = 0.699; Nagelkerke R Square = 0.934; ***$p < 0.001$; OR – odds ratio; CI – confidence intervals

The results showed that the binary logistic regression model was statistically significant, $\chi^2(5) = 546.65$, $p < 0.0005$. The model also explains 69.9% (Cox & Snell R Square) to 93.4% (Nagelkerke R Square) of the variance in image retake. Image retake occurred more likely in non-sthenic patients compared

with sthenic patients (OR = 95.16; 95% CI = 87.42-119.90), in non-ambulatory patients compared with ambulatory patients (OR = 175.59; 95% CI = 143.45-191.80), and in procedures involving the axial section of the body compared with the appendicular part of the body (OR = 1060.96; 95% CI = 997.68-1175.92). The patient (OR = 1.39; 95% CI = 0.41-2.71) and RT's sexes (OR = 1.75; 95% CI = 0.48-2.34) were not significant determinants of image retake ($p > 0.05$).

The present study found out that patient's body habitus and walking status, and type of examination are significant determinants of general DR image retake, which contradicts to a previous report (Akhtar *et al.*, 2016). Patients in general DR are classified into four body types, namely, sthenic, asthenic, hyposthenic, and hypersthenic. Asthenic and hyposthenic patients have slender and thin body while hypersthenic patients have massively built figures. The sthenic patients are those with average, athletic built form and are used as a reference for comparison among other body habitus. In general DR, radiographers are asked to position non-ambulatory hypersthenic or asthenic patients. It was described that one of the challenges faced by general DR nowadays is the difficulty in acquiring quality images from the said patients, which includes series of image-repeats only to attain the image with optimal diagnostic value (Adler and Carlton, 2013; Whitley *et al*., 2015).

As described by Andersen *et al*. (2012) and Foos *et al*. (2009), the procedures in general DR encompassed the structures in the axial region such as the chest, and skull/facial bones demonstrated the highest retake frequency. In general DR, most of the examinations involving the chest and skull/facial bones are conducted using Computed Tomography (CT) scan and Magnetic Resonance Imaging (MRI). Similar to the observation of Lin *et al*. (2016), radiographers may have less experience in handling general DR machines and thus, may commit more errors in handling the equipment which may then require image retake.

## 4. Conclusion and Recommendation

This study reported a very high and unacceptable image retake rate of 54.07% in general DR. Non-sthenic, non-ambulatory, young/middle-aged, and male patients demonstrated a higher occurrence of image retake. Procedures involving axial structures of the body exhibited a higher image retake

occurrence. Radiographers who are young, male, and less experienced committed a higher image retake occurrence than older, female, and more experienced radiographers. Hence, a possible solution in reducing image retake rate is to provide training courses for less experienced radiographers to increase their professional knowledge and technical skills in handling these radiographic procedures. Also, results of the logistic regression analysis revealed patient's body habitus and walking status, and the type of examination significantly predicted the occurrence of image retake. Therefore, intervention programs for image retake prevention in hospitals should target these significant determinants to attenuate the occurrence of image retake.

There are several limitations of this study. First, this study only included five hospitals in Southeastern Philippines; hence, future studies may be conducted in other regions of the country to validate the results of the present investigation. Second, equipment-related factors and other patients- and radiographer-related correlates not included in the study may be explored. Third, this study did not include measures or guidelines for decreasing image retakes in general DR. However, the findings may provide valuable information to general DR management in the conduct of regular quality improvement analysis, especially in mitigating the occurrence of high image retake. Nevertheless, the study described significant predictors of image retake that may be utilized in the formulation of quality indicators to decrease the frequency of image retake, thereby decreasing the amount of radiation dose most likely received by the patients.

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