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FULL PAPER

Radiographers' professional knowledge regarding parameters and safety issues in plain radiography: a questionnaire survey

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Objective: To review the knowledge of radiographers and examine the possible sociodemographic and situational contributors to this knowledge.

Methods: A questionnaire survey was devised and distributed to a cohort of 120 radiographers. Each questionnaire contained two sections. In the first section, background data, including sex, age, highest academic level, grade point average (GPA), length of time from graduation, work experience as a radiographer and the status of previous refresher course(s), were collected. The second section contained 17 multiple-choice questions concerning radiographic imaging parameters and safety issues.

Results: The response rate was 63.8%. In univariate analytic model, higher academic degree ($p < 0.001$), higher GPA ($r^2 = 0.11$; $p = 0.001$), academic workplace ($p = 0.04$) and taking previous refresher course(s) ($p = 0.01$) were significantly associated with higher

knowledge score. In multivariate analytic model, however, higher academic degree ($B = 1.62$; $p = 0.01$), higher GPA ($B = 0.50$; $p = 0.01$) and taking previous refresher course(s) ($B = -1.26$; $p = 0.03$) were independently associated with higher level of knowledge. Age, sex, length of time from graduation and work experience were not associated with the respondents' knowledge score.

Conclusion: Academic background is a robust indicator of a radiographer's professional knowledge. Refresher courses and regular knowledge assessments are highly recommended.

Advances in knowledge: This is the first study in the literature that examines professional knowledge of radiographers in terms of technical and safety issues in plain radiography. Academic degree, GPA and refresher courses are independent predictors of this knowledge. Regular radiographer professional knowledge checks may be recommended.

The Joint Commission on Accreditation of Healthcare Organizations mandates "processes that are designed to ensure that the competency of all staff members is assessed, maintained, demonstrated and improved on an ongoing basis." Tests with practical questions that reflect the knowledge required to perform daily examinations have been proposed as effective tools to attain this purpose. The results enable us to take on existing blemishes and improve the competency.¹

Medical imaging, as a field with growing complexity and increasing impact on diagnosis, plans of management and patient health status,² is a good example of raised requirements for competency.³⁻⁸

Knowledge assessment may be useful for detecting possible weaknesses in an organization and spotlighting existing

educational flaws and shortcomings.⁹ According to some reports, knowledge assessment takes priority over checking competency,^{7,10} particularly in professions that are completely mediated by technology.¹¹

In addition, although clinical education is the mainstay for developing skills, it has been shown that the combination of practical and theoretical education would lead to a significantly better outcome in the field of teaching. This integrated approach of using both knowledge and practice in education enables the trainee to work more competently and be prepared to take responsibility in his/her future career.¹²

Although radiography using film for imaging the internal organs of the body has been introduced for over a century,¹³

it is still among the most widespread and useful imaging modalities all over the world. Radiographers are generally in charge of radiological equipment, imaging examination and frequently nursing care.^{7,14,15}

Incompetent radiographers could render radiographic examinations suboptimal. A poor radiographic technique, in turn, may lead to unnecessary exposures to X-radiation, poor image quality, repeated views and examinations, patient discomfort or further injury because of poor positioning and the possibility of a missed diagnosis or misdiagnosis.¹⁶

Furthermore, a rapid shift from conventional to fully digitized radiology departments, along with rapidly evolving changes in healthcare administration¹⁷ entails knowledgeable, up-to-date radiographers who utilize the technology.¹⁸

Except for very limited number of studies that have described radiographers' self-reported competency^{7,16} and the level of awareness pertaining to the protection against radiation,^{19,20} to the best of our knowledge, there is no study in the literature regarding radiographers' level of knowledge with a dedicated focus on technical parameters and safety in plain radiography.

This study sets out to examine knowledge amongst a cohort of radiographers and to investigate possible association of some sociodemographic and situational factors with the level of this knowledge.

METHODS AND MATERIALS

After being approved by the ethics committee of Tabriz University of Medical Sciences, this multicentre, knowledge-assessment study was performed in 35 teaching and private medical imaging centres in the metropolitan area of Tabriz, Iran (including 11 university-affiliated hospitals, 11 independent radiology centres, 7 community hospitals and 6 private hospitals) from July 2013 through to November 2013.

A self-administered questionnaire was developed with two sections. The first section collected background data, including sex; age; highest academic level, including 2 years of university or associate degree (equivalent to Higher National Diploma in the UK) or 4 years' university or bachelor degree; grade point average (GPA) (Table 1) related to the highest academic level; length of time from graduation; work experience as a radiographer; workplace as affiliated (academic) or unaffiliated (non-academic) with a local university/college; and the status of previous refresher course(s) in radiography and its frequency while the second contained 17 questions on radiographic imaging parameters, as well as operator and patient safety (Table 2). Questions were in multiple-choice, tick-box format.

Correct answers to the questions were given a score of 1, while incorrect or blank answers were given a score of 0. Total knowledge score was the sum of 17 scores, ranging from 0, when no correct answer was ticked, to 17, when all the answers were marked correctly.

The validity of the questionnaire had been previously established by a panel of experts in our university and a filed test was

Table 1. International equivalents of grade point average (GPA) reported in the present study

Iranian GPA (range, 0–20)	International GPA	
	Range, A–F	Range, 0–4
0–9	E/F	0
10–11	D	1
12–13	C	2
14–15	B	3
16–20	A	4

Adapted from <http://www.wes.org>

conducted. Piloting the questionnaire on 26 participants (not from current sample) to test its reliability showed a good internal consistency (Cronbach's $\alpha = 0.74$).

The questionnaire was first piloted with two lecturers in radiologic technology (with 7 and 11 years' experience), and some minor changes in the questionnaire format were made.

Recruitment involved convenience sampling, and the inclusion criteria were as follows: (i) having a valid practicing licence in radiologic technology; (ii) having a relevant academic degree obtained from accredited nationwide universities; and (iii) being clinically active and presently working as a radiographer.

At the time of the survey, 188 radiographers fulfilled the criteria. All questionnaires were distributed along with an explanatory letter containing information about the survey and ethical aspects. Collecting boxes were made available at each medical imaging centre, and all radiographers were asked to return the questionnaire no later than 3 months from the date of receipt. Reminding e-mails were sent 1 week prior to deadline to all 188 radiographers. To assure anonymity, a non-radiographer from the staff at each centre acted as a communication broker between researchers and participating radiographers.

STATISTICAL ANALYSIS

Data analysis was performed using SPSS® v. 16 (SPSS Inc., Chicago, IL). Normal data distribution was confirmed using Kolmogorov–Smirnov testing and drawing QQ-plots. Independent samples *t*-test was used to compare numerical data. Pearson product–moment correlation coefficient (r^2) was calculated to examine correlations. The linear regression model was used for investigating independent associations. *p*-values <0.05 were considered statistically significant.

RESULTS

A total of 120 radiographers completed the questionnaire, a response rate of 63.8%.

The respondents were 64 males (53.3%) and 56 females (46.7%) with a mean age of 35.5 ± 8.7 years [minimum–maximum (min–max), 23–62 years].

The highest academic level was associate degree in 46 respondents (38.3%) and bachelor degree in 74 others (61.7%); with a mean GPA of 15.7 ± 1.5 (min–max, 13.0–18.6).

Table 2. Questions in the second section of the questionnaire and the number (%) of correct answers by radiographers

Question		Correct answer
1	From a patient with normal weight and height to a fairly overweight one, which exposure factors would you consider the most important to be changed?	82 (68.3)
A)	kV	
B)	mA	
C)	s	
D)	mAs	
2	When a patient's condition does not allow object-film distance minimization, which one of the following methods would you opt for?	85 (70.8)
A)	Would put a sponge between the object and film	
B)	Would decrease FFD	
C)	Would Increase FFD	
D)	No change would be needed	
3	How strictly would you adhere to "FFD = 100 cm" during a routine radiography?	77 (64.2)
A)	I would not follow it strictly, because it has no significant effects on the exposure factors	
B)	I would not follow it strictly, as it has no significant effect on density and contrast within the distance latitude	
C)	I would adhere strictly, because it significantly affects the exposure factors	
D)	I would adhere strictly, because it has been emphasized by the mentors and in the literature	
4	For spectral matching between film sensitivity and the light emitted from the screen, which one is correct?	52 (43.3)
A)	Decreasing patient dose-increasing X-ray tube lifetime	
B)	Increasing quality of radiograph-decreasing exposure time	
C)	Increasing image resolution-increasing film contrast	
D)	Decreasing image unsharpness-increasing image sharpness	
5	What screen-film combination do you use at your department?	49 (40.8)
A)	Routinely a fast screen-film combination	
B)	Both fast and slow screen-film combinations	
C)	Routinely a slow screen-film combination	
D)	I don't know	
6	Changing which exposure factor may yield the clearest image of the cardiac wall, using chest X-ray radiography?	38 (31.7)
A)	kV	
B)	mA	
C)	s	
D)	mAs	
7	What would your reaction be to the production of ionized air in radiology room?	10 (8.3)
A)	I would enter the room briefly after exposure	
B)	I would turn on the air conditioner as soon as exposure is done	

(Continued)

Table 2. (Continued)

Question		Correct answer
C)	I would turn on air conditioner before exposure	
D)	I would not consider it necessary to turn on the air conditioner	
8	To examine the lungs in chest X-rays is usually used	40 (33.3)
A)	High kV- to diminish skin dose	
B)	High kV-to make the shadow of the ribs fade	
C)	High kV-to increase image density	
D)	High kV- due to the presence of the ribs and the thoracic vertebrae in the exposure field	
9	Which exposure factor would you change to repeat radiography with an appropriate contrast and low density for an uneasy patient?	80 (66.7)
A)	kV	
B)	mA	
C)	s	
D)	mAs	
10	What is your opinion on writing a patient's history on a radiology request form?	99 (82.5)
A)	It is of less importance compared with other information on the form	
B)	It is needed to save on film use	
C)	It is essential for selecting and implementing the appropriate technique	
D)	I do not find it of much use	
11	Which one might be the most important approach to enhance the quality of the image for abdominal radiography, using a portable machine?	79 (65.8)
A)	Using low kV and high mAs	
B)	Using high kV and low mAs	
C)	Increasing FFD	
D)	Using gridded cassettes	
12	Why is there an increased exposure during bucky-aided abdominal radiography in standing compared with lying position?	51 (42.5)
A)	To better visualize the air-fluid level	
B)	Because of the increased abdominal thickness in standing position	
C)	Because of the diminished energy and intensity of X-rays under the influence of gravity	
D)	To compensate for the diminished intensity of X-rays due to the increased FFD	
13	What is the reason of not allowing the edges of both radiation field and object to exceed 2 cm?	87 (72.5)
A)	To increase image quality	
B)	To decrease exposure	
C)	To save on film use	
D)	To save on film processing agent consumption	

(Continued)

Table 2. (Continued)

	Question	Correct answer
14	What might be the cause of "air trapping" artifact?	33 (27.5)
A)	The bubbles developed in film processing liquids	
B)	A gap between target and film	
C)	Intestinal gas movement	
D)	Rapid cassette closing	
15	Why would a cassette without a screen be used?	88 (73.3)
A)	To decrease patient radiation exposure	
B)	To enhance image details	
C)	To decrease image distortion	
D)	To decrease penumbra and unsharpness	
16	What is the most important shortcoming in using a cassette without a screen?	81 (67.5)
A)	Diminished image sharpness	
B)	Increased patient radiation exposure	
C)	Diminished cross-over exposure	
D)	Decreased image contrast	
17	In which condition might there be more flexibility in the selection of exposure factors?	31 (25.8)
A)	Using fast film-screen combination	
B)	Using film without screen	
C)	Using slow film-screen combination	
D)	Using automatic film processor	

FFD, film-focus distance.

The mean length of time from graduation was 12.1 ± 6.7 years (min-max, 2–32 years).

The mean work experience was 10.2 ± 8.0 years (min-max, 1–30 years).

Workplace was academic in 87 cases (72.5%) and non-academic in 33 cases (27.5%).

Previous refresher course(s) were taken by 57 respondents (47.5%). The mean number of previous full refresher courses was 3.0 ± 1.4 , including once in 13 cases (22.8%), twice in 7 cases (12.3%), three times in 14 cases (24.6%), four times in 16 cases (28.1%), five times in 6 cases (10.5%) and six times in 1 case (1.8%).

Characteristics of the sample are presented in Table 3.

The mean knowledge score was 8.9 ± 3.0 (min-max, 1–14). It was 9.3 ± 3.0 (min-max, 2–14) in males and 8.4 ± 3.0 (min-max, 1–13) in females, with no significant difference between the two groups (independent samples *t*-test $p = 0.10$).

Rates of correct answers for each question in the employed questionnaire are shown in Table 2.

No significant correlation was found between knowledge score and the respondents' age ($r^2 = 0.005$; $p = 0.49$).

The mean knowledge score was significantly higher in respondents with a bachelor degree than in those who held an associate degree (9.7 ± 2.5 , min-max, 2–14; and 7.4 ± 3.2 , min-max, 1–13; independent samples *t*-test $p < 0.001$) (Figure 1).

No significant correlation was present between knowledge score and the length of time from graduation ($r^2 = 0.006$; $p = 0.40$).

Knowledge score significantly correlated with GPA ($r^2 = 0.11$; $p = 0.001$) (Figure 2). By contrast, the score and work experience were not correlated significantly ($r^2 = 0.006$; $p = 0.40$).

The mean knowledge score was significantly higher for radiographers in an academic workplace than for their counterparts in a non-academic environment (9.2 ± 2.7 , min-max, 3–14; and 8.0 ± 3.4 , min-max, 1–13; independent samples *t*-test $p = 0.04$) (Figure 3).

The respondents with a positive history of taking refresher course(s) scored significantly higher than the radiographers with no previous refresher course (9.6 ± 2.5 , min-max, 3–13; and 8.1 ± 3.2 , min-max, 1–14; independent samples *t*-test $p = 0.01$) (Figure 4).

There was a direct, but marginally insignificant correlation between knowledge score and number of previous refresher course(s) ($r^2 = 0.06$; $p = 0.06$).

Table 3. Characteristics of study sample ($n = 120$)

Sex	
Male	64 (53.3)
Female	56 (46.7)
Age (years)	
Total	35.5 ± 8.7
Males	38.9 ± 8.6
Females	31.8 ± 7.2
Highest academic level	
Associate degree	46 (38.3)
Bachelor degree	74 (61.7)
Grade point average ^a	15.7 ± 1.5
Length of time from graduation (years)	12.1 ± 6.7
Work experience (years)	10.2 ± 8.0
Workplace	
Academic	87 (72.5)
Non-academic	33 (27.5)
Previous refresher course(s)	
Yes	57 (47.5)
No	63 (52.5)
Number of previous refresher course(s)	3.0 ± 1.4

Data are presented as number (%) or mean $\pm$ standard deviation.

^amin-max, 0–20.

Table 4 represents the outcome of the regression model. The R^2 and adjusted R^2 for the model were 0.26 and 0.23, respectively. The knowledge score was significantly associated with academic

degree, taking previous refresher course(s) and GPA. The workplace was not significantly associated with the respondents' knowledge score in this model.

DISCUSSION

Competency of healthcare professionals has always been considered an indispensable and, at the same time, a challenging concept.^{21,22}

The competency itself, on the other hand, is not a single, uniform entity and encompasses other components such as skill, ability and knowledge.²³ These components altogether ensure safety and the high-quality, cost-effective services.^{15,23,24}

This is why competency-based descriptions of professional practice do not adequately capture the essence of professional knowledge,¹⁰ particularly in professions that are completely mediated by technology, such as radiography.¹¹

In a series by Andersson *et al*,⁷ radiographers' self-assessed level and use of competencies were examined, and some socio-demographic and situational factors in relation to these competencies were reported. The authors found that both the level and use of several competencies differed in line with age, number of years in present position and workplace. A regression model, however, revealed that these three factors explained a relatively small part of competency. Accordingly, the authors concluded that a multidimensional situation with other possible factors of importance, such as the radiographer's own level of knowledge, may exist.

For the first time in the literature, the present work examined technical knowledge in plain radiography amongst a cohort of radiographers and identified three independently associated factors: academic degree, GPA and previous refresher course(s).

Figure 1. The mean knowledge score of radiographers by their academic degrees. * $p < 0.001$.

Figure 2. Scatter plot depicting knowledge score of radiographers (x-axis) vs grade point average. $*r^2 = 0.11$; $p = 0.001$.

While no significant role was found for age, sex and work experience, in conformity with the previous report,⁷ a significant, albeit non-independent, connection was present between the level of knowledge and workplace.

In a previous study, Foley et al²⁰ tried to assess the knowledge of a cohort of radiographers in CT parameters and their influence on patient dose and image quality. In line with our finding, they

reported that the level of experience did not significantly affect the number of correctly answered questions.

The presence of no association between work experience and the level of knowledge is a dramatic finding.

Traditionally, many years of experience has been considered a pre-requisite for gaining increased skill and competency.²⁵ The

Figure 3. The mean knowledge score of radiographers by their workplace. $*p = 0.04$.

Figure 4. The mean knowledge score of radiographers by the status of previous refresher course(s). * $p = 0.01$.

number of years of experience, however, does not necessarily ensure turning from a novice into an expert.²⁶

It has been suggested that routines in the clinical situations are usually based on unconscious habitual behaviours rather than theoretical knowledge.^{27,28} When these “routines” are not based on scientific information or are developed in compliance with outdated regulations, the experience is just a fallacy. Now in this condition, when there is no supervision and correcting attempts regularly, the problem continues with its existence and even may get worse. To overcome this hurdle, regular quality assessment programmes have been emphasized in previous reports. Such programmes could efficiently promote high standards, guarantee patient safety, and instill confidence in radiographers.^{20,29–31} Competency requirements for radiographers to have a licence retained have been suggested as another option to resolve such problems.¹⁶ Knowledge assessment examinations could be embedded in this licence-renewal regimen.

Another likely justification for an insignificant association between work experience and knowledge is the possible fading of learnt concepts from the radiographer’s memory over time. This possibility demands another important measure, which is the

need of regular refresher courses, updates or continuing education.^{16,20,32} Interestingly, mean knowledge score of those radiographers with attendance in refresher course(s) was significantly, and in an independent manner, higher than the score of their counterparts who had not taken previous course(s).

Although small ($r^2 = 0.06$) and marginally insignificant ($p = 0.06$), the presence of a positive correlation between knowledge score and number of previous refresher course(s) in the present work further corroborates this notion that continuing education is an indispensable part of a successful knowledge promotion strategy among radiographers.

Started for the first time in 2005, the refresher course for radiographers in our institute comprises 12 topics regarding technical considerations and safety issues in radiography. This course is held throughout the year, including one topic for each month. At the beginning of each month, participants are provided with pamphlets, including photocopies of the related topic extracted from reference books/journals, plus newly published related articles retrieved from the internet. After 1 month of self-study and consultation with mentors in the cases of extra help, the participants take the final examination. Participation in

Table 4. Results of multivariate analysis for detecting independent determinants of knowledge score of radiographers among significant variables in univariate analysis ($n = 120$)

Variable	<i>B</i>	95% confidence interval for <i>B</i>	<i>p</i> -value
Academic degree	1.62	0.45–2.79	0.01
Workplace	0.38	–0.86–1.61	0.55
Previous refresher course(s)	–1.26	–2.41–0.11	0.03
Grade point average	0.50	0.13–0.88	0.01

“*B*” represents the coefficient of the estimated regression model.
 p -value < 0.05 is statistically significant.

refresher course is not mandatory, but attendees can earn education credits if they participate and pass all the examinations.

The lack of a significant correlation between knowledge score and the length of time from graduation in the current survey indicates that these refresher courses should not be confined exclusively to experienced cases, that is, those who had worked as radiographers for many years.

Two other independent predictors of higher knowledge score in the present study were academic level (bachelor *vs* associate degree) and GPA. These findings are not unexpected surprises. Education has been previously proposed as a factor with major importance in predicting competence of radiographers in their future professional lives. Accordingly, placing more emphasis on the education system and quality improvement projects in clinical practice has been suggested for training competent radiographers.⁷ Our findings, however, suggest that this pivotal influence of education on radiographers' competency is possibly through its effect on the knowledge component.

Last but not least, a significant association was documented between workplace (academic *vs* non-academic) and knowledge score in the present survey. Such a significant relationship, however, was absent in multivariate analytic models.

Unlike most radiology administrators in private centres,³³ there is a tendency towards baccalaureate level radiologic technologists, in comparison with those with lower academic ranks, in university-affiliated imaging departments. In addition, employment at university-affiliated medical imaging centres and academic tenures is usually available for those with higher academic achievements, particularly higher GPAs.³⁴ As a consequence, employees of academic workplaces are more likely radiographers with a bachelor degree and with high GPAs. Thus, a workplace in a multivariate analytic model with both academic degree and GPA would stand no chance of emerging as an independent predictor of knowledge score.

A conspicuous finding in the present work was a rather low mean knowledge score by participants (8.9/17 = 52.4%). This finding may indicate the presence of one or more poorly answered questions by a large number of participants. As summarized in Table 2, the rate of correct answers to the question numbers 7, 17, 14, 6, 8, 5, 12 and 4 was <50%; that is, 8.3%, 25.8%, 27.5%, 31.7%, 33.3%, 40.8%, 42.5% and 43.3%, respectively. The best correct answer rate, on the other hand, belonged to the question number 10 (82.5%), followed by the question numbers 15 (73.3%), 13 (72.5%), 2 (70.8%), 1 (68.3%), 16 (67.5%), 9 (66.7%), 11 (65.8%) and 3 (64.2%). Although based on available information putting forward a particular trend in answers by participants would not seem rational, these findings may be useful in terms of targeting/proposing future refresher courses; noting that a number of the poorly answered questions are directly connected with the safety of the operator and patient.

This study suffers from some limitations that should be acknowledged. Inherent selection bias has always been a concern in knowledge assessment studies, because it is thought that

respondents who are more confident of their answers are more likely to participate. In addition, although participants were asked not to refer to information sources during answering the questions, this could not be guaranteed given the nature of the study.²⁰

The response rate in the current survey was dominated by academics, potentially skewing the results concerning the overall level of radiographers' knowledge. This imbalance is owing to the policy of recruiting all active radiology centres in the target area. Since the results were stratified by academic and non-academic participants, however, our other primary purpose to find out possible contributors to radiographers' knowledge was unaffected. Nonetheless, a better idea of the initial pool of sites is needed for future studies.

Another possible limitation is that this study was confined to the metropolitan area, so the results may not be confidently generalized to radiographers working in suburban and rural areas and results may differ. The reason we performed this study in a metropolitan area was that the number of active radiology centres outside this area was very low.

No information was collected regarding the time of the last refresher course taken by the participants in the present study, because this programme had been started recently (from 2005), and the authors did not expect a significant role for this factor. In future studies, however, a possible contributor to the level of radiographers' knowledge would be the time between the last refresher course and the knowledge assessment.

Using a short questionnaire with 17 questions may seem inadequate to make conclusions on radiographers' overall professional knowledge and perhaps to draw conclusions on the whole population of radiographers. Although a lengthy questionnaire, as compared with a short one, may encompass more details, it has been shown that there is a significant negative correlation between a questionnaire length and the response rate, particularly when the recruitment is on a voluntary basis.³⁵

Facing a trade-off between more questions and a larger sample, the authors chose the latter. With no sense of exaggeration, the employed questionnaire in the present work deals with most of the technical and safety key points in the field of radiography. Despite this justification, however, future studies could use larger questionnaires in this regard.

Finally, small correlation between knowledge score and GPA ($r^2 = 0.11$), small and marginally insignificant correlation between knowledge score and the number of previous refresher course(s) ($r^2 = 0.06$; $p = 0.06$) and documentation of fitting results that were not ideal (goodness-of-fit $R^2 = 0.26$ and adjusted $R^2 = 0.23$) may insinuate that a more complex environment with extra factors playing roles in predicting knowledge scores of radiographers may exist. Further studies in this regard may elucidate this ambiguity.

It should be noted that only full refresher courses (12 months) were counted as the number of previous refresher course(s) in the present survey. As a result, participants with incomplete

participation(s) were not able to be excluded. This may also justify the small correlation found between knowledge score and the number of previous refresher course(s).

CONCLUSION

This is the first study in the literature that examines radiographers' knowledge in terms of the technical part of professional knowledge with a focus on the parameters and safety in plain radiography. Academic background, namely academic degree and GPA, predicts

radiographers' level of technical knowledge, independently. Refresher courses and regular knowledge assessments may possibly enhance this kind of knowledge in radiographers. Since radiographers' professional knowledge is associated with their performance and patients' safety, the results of the present study are clinically important, too.

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