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A study to understand the acceptance of DICOM Structured Reports on Breast Imaging

Liliana Tribuna[a*], Augusto Silva[b], Pedro Sá Couto[c], Luis Bastião[d]

[a] *Department of Radiology, Hospital da Luz, Aveiro, Portugal*
[b] *DETI/IEETA, University of Aveiro, Portugal*
[c] *CIDMA/DMAT, University of Aveiro, Portugal*
[d] *BMD Software, Lda. Portugal*

Abstract

Purpose: To create a *Digital Imaging and Communication in Medicine Structured Reports* (DICOM-SR) Repository and compare the acceptance of Free Text (FT) *versus* Structured Reports (SR) in communication of Breast Imaging findings.
Materials and Methods: It was conceptualized the *MamoCatalogue* to the structuring of the Reports and the SR were converted into DICOM-SR and integrated with *Dicoogle*. After that, seven representative Breast Imaging Reports were selected and evaluated by a group of 25 Physicians. Each Physician evaluated the seven Reports, in FT and SR with a 3 months timelag, about their, Structure, Clarity and assertiveness, Diagnostic/Recommendations, Easiness of reading, Full reading, Partially reading with *Breast Imaging Reporting and Data System* (BI-RADS) focus and Ambiguity.
Results: A DICOM-SR Repository was created and the assessment of the acceptance of the FT *vs.* SR revealed that there is a global trend favoring FT. Nevertheless, a group wise analysis revealed that for Gynaecologists and General Practitioners (GP) the differences between FT and SR weren't significant, unlike what happens with Radiologists.
Conclusion: The DICOM-SR Repository allows the query/retrieve data for Reports and the communication with Gynaecologists and GP by SR was satisfactory. Although, Radiologists acceptance must be reinforced upon global communication and management strategy.

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* Corresponding author. Tel.: +0-000-000-0000 ; fax: +0-000-000-0000 .
E-mail address: lilianatribuna@ua.pt

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Keywords: Breast cancer; Free Text; Structured Reports; DICOM Structured Reports.

1. Introduction

The incidence of Breast Cancer has been increasing over the past 20 years and its diagnosis has been performed in increasingly young patients [1]. Demographic trends estimate a continuous increase of the values mentioned above, therefore early diagnosis and the optimization of the treatment are fundamental elements for the reduction of mortality rate and the increased of survival of patients with Breast Cancer [1, 2, 3]. The Imaging Examinations play a fundamental role in the diagnosis and prognosis of this pathology [1], and the effective communication of Imaging findings is a crucial element in the diagnostic by imaging, and to promote the best patient care and support for the requesting Physician [4].

Since the beginning of time, Reports could take one of two forms, *Free Text* (FT) or *Structured Reports* (SR) [5]. In 2000 the *Digital Imaging and Communications in Medicine - Structured Reports* (DICOM-SR) was published and defined the data structure for the construction of a *SR* in DICOM format [6]. Thus, due to the potential of this type of documents, particularly in the area of the Breast Imaging, this article describes the concept of a DICOM-SR Repository in Breast Imaging, where it is possible to search, query and analyse data and, in addition, compares the acceptance of Radiologists and non-Radiologists by FT *versus* SR, in the reporting of Breast Imaging findings.

2. Background

2.1. Radiology Reports

The FT, used in the majority of the cases, usually does not have an explicit reporting structure and its methodology of writing is based on the Radiologists professional experience, which can result in narratives extremely subjective evaluations [6]. The reduction of this variability should be promoted, because the *Standard* Reports will facilitate the understanding of these documents by the requesting Physicians [7]. On the other hand, the SR present their organized contents in a clear and organized form, based on *Templates* or *Checklists* and three essential properties are recognized: structured format, consistent organization and standardized language [8]. This type of report has the purpose of implementing the concept of standardization of the Clinical Reports and to promote their continuous improvement [9], promising to increase the consistency of the Report, increase the productivity of the Radiologists and improve the communication of the results with the requesting Physicians [7, 10].

With consistent format and terminology, the SR allow recovery and analysis of information from the Report, both by humans and by Information Systems (IS), in order to support the medical research, the clinical decision, to support the Quality Improvement (QI) processes, and, also, to evaluate inherent characteristics to the Reports [7, 11]. The successful implementation of SR is a difficult task, because it is dependent on the Radiologists acceptance.

2.2. DICOM-SR

The *Digital Imaging and Communications in Medicine* (DICOM) standard proposes a set of rules for coding, storage and transfer of medical information and ensured the interoperability between the various entities of the *Picture Archiving and Communication System* (PACS), regardless of the equipment and manufacturer type that, otherwise, would be incompatible [12]. Given its potentiality, an extension of the same was published, that aims the implementation of SR in DICOM format, defining the constitution of objects that encode the information of Clinical Reports, as well as their relationships [13].

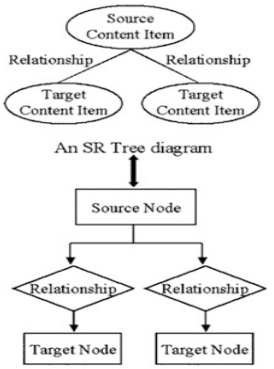

Figure 1 – Diagrams of SR trees [14].

The DICOM-SR files have a *Header*, which encodes the information of the patient and study identification, and the *Content Tree*, responsible for the coding of the Report itself. The latter has the information elements hierarchically connected, in a tree model, identifying the *Sources* and *Targets Node*s and their relationships (Figure 1). Each element of information has a name and a value, forming the pairs Name-Value [13, 14, 15]. The DICOM-SR are defined for sharing, viewing and storing of *SR*, allowing the increase of the accuracy and value of Clinical Reports. There are many inherent benefits to this type of documents, highlighting the best communication with the requesting Physician, to obtain more precise diagnostics, greatest speed and less fatigue in the Report, consistent identification information, archive support, transfer and/or simultaneous manipulation with the target object of report and the possibility of relevant referencing, through hyperlinks [15]. In addition, the use of this type of Reports allows the execution of *data mining* actions to the Reports database [12].

The DICOM-SR has developed the *SR Templates*, defining several standard structures of application [14], and the *Breast Imaging Report Templates* define the structure and the coding for a Report of Breast Images [16]. The DICOM-SR *Part 16: Content Mapping Resource* describes the DICOM terminology used throughout its *Templates* [17], specifying the *DICOM Content Mapping Resource* (DMCR), which defines the terminology by the integration of multiple Lexicons and their value assignment for representation in DICOM format [18].

2.3. PACS

The concept of PACS consists of a set of subsystems for the image acquisition and digital information, storage and visualization, integrated by digital networks and appropriate software [19]. It was developed in order to respond to the high needs for storage and transmission of medical information in clinical institutions [20]. The PACS uses the DICOM standard, however a common problem is the fact that the Imaging study be stored in this system and their Reports are to be managed by the *Radiology Information System* (RIS) or *Hospital Information System* (HIS). Delegating the management and storage of the Imaging Reports to the PACS, using the DICOM-SR can be the solution [21].

The *Dicoogle* is an *open-source* PACS, which is distinguished from the others systems to possess a more agile mechanism for indexing and recovery, allowing the indexing of any type of document. Thus, adding all the others DICOM metadata, the *Dicoogle* can automatically remove, index, and store all metadata discovered in the Header DICOM, including the *private DICOM attribute tags*, with no need for reconfiguration and/or re-engineers [22].

3. Materials and Methods

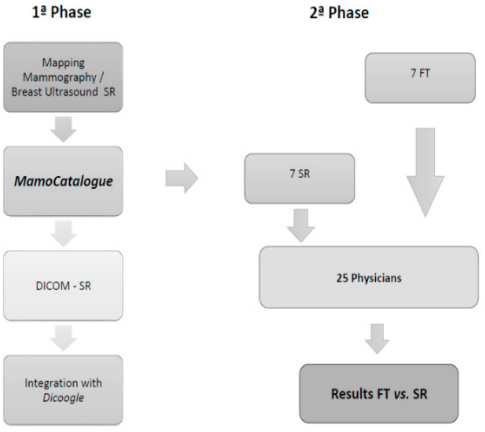

Figure 2 - Flowchart of research actions.

The research was conducted in Hospital da Luz Aveiro and consisted of two stages, the first in the creation of the Repository DICOM-SR and the second in the evaluation of the communication of Breast Imaging findings of the FT *versus* SR. In Figure 2, we present the flowchart of research actions, with the several undertaken steps, for better understanding.

The first phase was initiated with the mapping of all possible fields in the Mammography and Breast Ultrasound Reports. This mapping was based on *Breast Imaging Report Templates* of standard DICOM and in DICOM terminology, with help of the *European Medical Information Framework Catalogue* (*EMIF* Catalogue). The EMIF Catalogue allows users, create their own *database fingerprint*, to create an appropriate form to its database[23]. In our case, it enabled the creation of a form with all the components (all the issues, as well as all the possible answers) that should be in the Report of Mammography and/or Breast Ultrasound. The form was created in an Excel document and it was later imported into the online EMIF Catalogue platform, which allowed the introduction of SR of Mammography and/or Breast Ultrasound, constituting the *MamoCatalogue* (Figure 3). These SR were later converted into the DICOM-SR format, with help of the tool *wildcard2cmd-sr*, developed by *Matos et al*. [24] and, subsequently integrated into the *Dicoogle* – PACS open source.

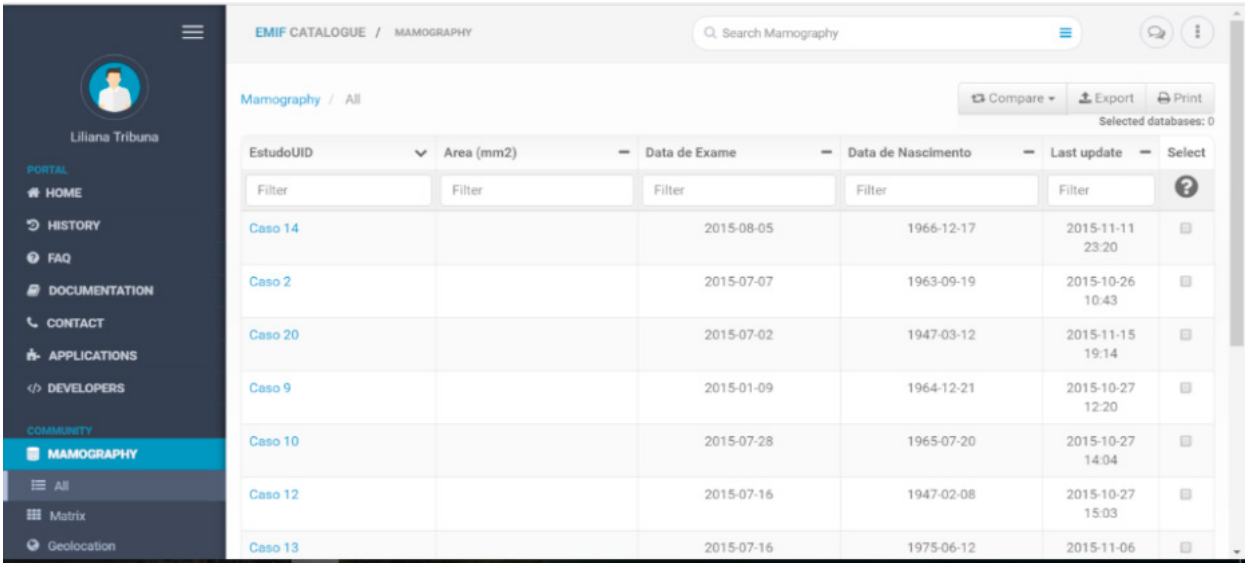

Figure 3 - Interface of the *MamoCatalogue*. Available in http://bioinformatics.ua.pt/catalogue-mamo/.

In the second phase a sample of 25 Physicians was gathered, from the specialties of Radiology, Gynaecology/Obstetrics and General Practioners (GP). The sample collected beheld the specialties of Gynaecology/Obstetrics and GP, for these are the responsible for the requisition of a large part of the Breast Imaging Examinations and, the specialty of Radiology, because Radiologists are responsible for the preparation of Imaging Reports. The sample was submitted to two different moments of evaluation, as suggested by *Barbosa et al*. [6] and *Johnson et al.* [9], first with the analysis of the FT and after at least 3 months, with the evaluation of the same Reports in the SR format. The selection of the Reports for analysis was performed in the following way: seven reports were defined for appreciation, because they are seven categories of classification *Breast Imaging Reporting and Data System* (BI-RADS) [25]; we opted for examining a report from each one of the categories BI-RADS, for these are closely

related to the degree of abnormality in the examination and, therefore, with the descriptions of the Imaging findings [26]; the selected Report was drawn randomly, within a set of possible Reports.

For the data collection performed in the second phase of the research a Questionnaire (Figure 4) was used, which composed of two distinct parts and for closed answer [27]. The first part of the Questionnaire concerns the analysis of the FT and, in addition to the demographic data, is constituted by a block of seven questions, which should be answered for each of the examined Reports. The second part is identical to the previous one, however concerning the SR. The demographic data selected will characterize the sample and were the following: Age, Gender, Specialty and Years of service. The issues that formed the body of the Questionnaire were based on the literature concerning good practice in the Imaging Reports and the pros and cons of the FT and SR, and were as follows: Structure[7], Clarity and assertiveness[7], Diagnostic/ Recommendations[4], Easiness of reading[7], Full reading[28], Partially reading with BI-RADS focus[28], and Ambiguity [6]. The first four issues were listed on the 5-point satisfaction Likert scale, as *Marcovici et al.* used in their research[29] and assumed values of Not satisfied (1) to Totally satisfied (5). The remaining issues, of binary nature, were answered in the Affirmative or Negative [30].

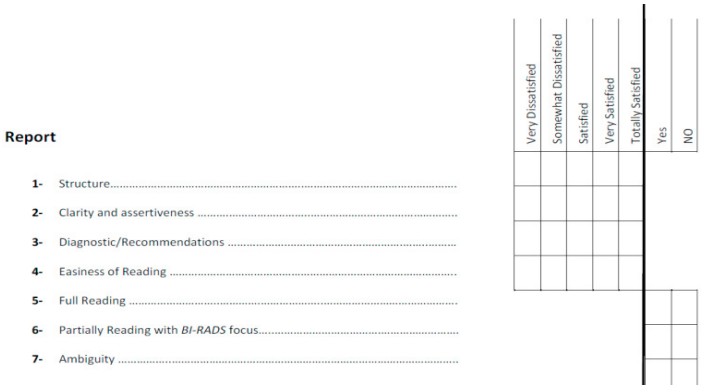

Figure 4 - Questionnaire used as evaluation instrument.

4. Results

As a result of the first phase of the investigation, the *MamoCatalogue* was created, an online platform that enables the creation, file and research of SR. In this platform it is possible to enter Mammography and/or Breast Ultrasound Reports, in Portuguese, using the DICOM terminology. The users, in order to make the report, go through the form and, using the checklist, will respond to the issues they consider applicable, by selecting the appropriate responses. Text boxes are available in all issues, allowing the Radiologists to complement their answers, or, if they are not satisfied with the terminology, use the FT. In addition to multiple choices answers, there are also issues of data type, Yes/No type and numerical type. The *MamoCatalogue* is available in *http://bioinformatics.ua.pt/catalogue-mamo/*, for authorized users and already has 51 SR of Mammography and/or Breast Ultrasound. Subsequently, the SR were exported from *MamoCatalogue* in CSV format and converted, through the *wildcard2cmd-SR* tool, for the DICOM-SR format and finally integrated with the *Dicoogle*, conceptualising the DICOM-SR Repository. The construed DICOM-SR documents were, thus, stored in *Dicoogle*, being able to perform researches (Figure 5) and queries to the documents, by setting the desired attributes. The images corresponding to each DICOM-SR may also be stored in *Dicoogle*, allowing the visualization of Report and Images simultaneously and on the same workstation. In a system of this type, the file, handling and management of Reports and Images is carried out jointly.

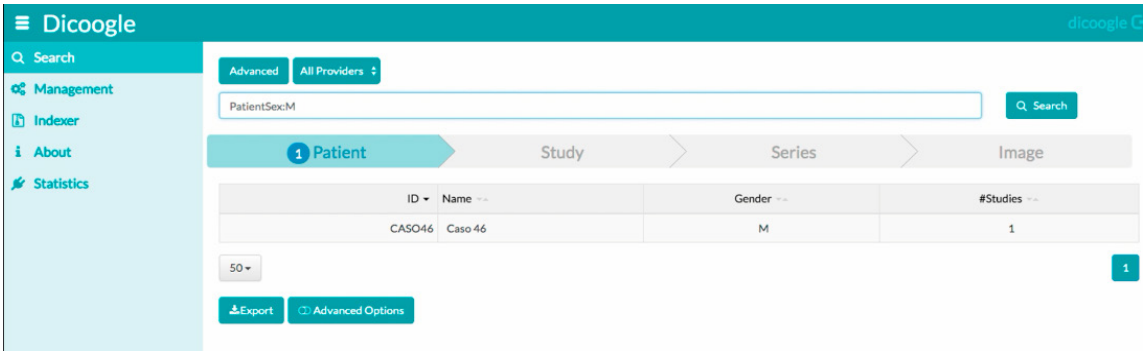

Figure 5 – Illustrative figure of a research conducted to the DICOM-SR integrated with the *Dicoogle,* with the attribute *"PatientSex:M"*.

In the second phase of the investigation, 28 % of the respondents had a specialty of Radiology (n=7, Age=41,3 ± 6,2), 36% of Gynaecology/Obstetrics (n=9, Age=50,6 ± 12,1) and 36% of GP (n=9, Age=60,4 ± 8,8). The Physicians questioned had on mean ± standard deviation (SD) ± 13.2 years of service. Based on the analysis of the Table 1, there is a global trend favouring the FT at the expense of the SR, for Structure, Clarity and Assertiveness variables, Diagnostic/ Recommendations and Easiness of Reading, revealing the considerable differences tested (*p value* < 0.05). The Physicians are, on mean (SD), 3,93 (0,86) satisfied with the Structure of the FT and 3,21(0,98) with the SR, the Clarity and Assertiveness was listed with on mean (SD) of 3,96 (0,80) for the FT and 3,39 (1,03) for the SR, and the Diagnosis / Recommendations obtained a satisfaction mean (SD) of 4,04 (0,83) for the FT and 3,50 (0,94) for the SR. However, the same cannot be verified when the FT *vs.* SR differences are tested for each of the medical specialties. For Gynaecology/Obstetrics, although the tendency for the FT, the measured differences FT *vs.* SR were not significant for any of the variables under study (Table 2) and, the same occurs for the group of GP (Table 3). Otherwise, it was in the Radiology speciality (Table 4) that significant differences were found, in particular for the variables Report Structure, Clarity and assertiveness and Diagnosis and recommendations.

Table 1 - Comparison of the global results FT *vs.* SR.

	FT	**SR**	**Differences**	
	Mean (SD)		**Mean (SD)**	***P value***
Structure	3,93 (0,86)	3,21 (0,98)	0,71 (0,98)	0,001
Clarity and assertiveness	3,96 (0,80)	3,39 (1,03)	0,57 (1,01)	0,010
Diagnostic / Recommendations	4,04 (0,83)	3,50 (0,94)	0,54 (0,97)	0,011
Easiness of reading	3,97 (0,84)	3,42 (0,98)	0,55 (0,99)	0,011
	Ratio of evaluated answers with YES		***P value***	
Full reading	0,97	0,87	0,044	
Partially reading with BIRADS focus	0,21	0,19	0,812	
Ambiguity	0,17	0,31	0,012	

Table 2 - FT *vs.* SR – specialty of Gynaecology/Obstetrics

	FT	**SR**	**Differences**	
	Mean (SD)		**Mean (SD)**	***P value***
Structure	3,78 (0,83)	2,99 (0,97)	0, 879 (1,15)	$0{,}075_1$
Clarity and assertiveness	3,89 (0,70)	3,43 (0,90)	0,46 (0,99)	$0{,}155_2$
Diagnostic / Recommendations	3,85 (0,78)	3,41 (0,92)	0,43 (1,03)	$0{,}233_2$
Easiness of reading	3,83 (0,79)	2,99 (0,87)	0,51 (0,97)	$0{,}106_2$
	Ratio of evaluated answers with YES		***P value***	
Full Reading	0, 98	0,83	0,051	
Partially reading with BIRADS focus	0,17	0,11	0,673	
Ambiguity	0,19	0,33	0,160	

1 – Paired sample t test
2 – wilcoxon signed rank test

Table 3 - FT vs. SR – specialty of GP.

	FT	**SR**	**Differences**	
	Mean (SD)		**Mean (SD)**	***P value***
Structure	4,13 (0,90)	3,71 (1,10)	0,41 (0,74)	0,131
Clarity and assertiveness	4,06 (0,90)	3,71 (1,37)	0,35 (1,08)	0,362
Diagnostic / Recommendations	4,14 (1,00)	3,81 (1,23)	0,33 (0,92)	0,317
Easiness of reading	4,19 (0,86)	3,81 (1,28)	0,38 (0,94)	0,258
	Ratio of evaluated answers with YES		***P value***	
Full reading	0,94	0,97	0,681	
Partially reading with BIRADS focus	0,29	0,27	0,908	
Ambiguity	0,14	0,27	0,283	

Table 4 - FT *vs.* SR – specialty of Radiology.

The interaction results between the Specialities and Type of Report were non-significant, meaning that the response patterns were identical (FT scores were higher than SR scores) for all the variables presented. Despite differences between FT *vs.* SR scores were significant only for the Radiologists. The influences of Age and Years of Service in the Results were non-significant.

5. Discussion

For the execution of the research a mechanism for structuring Mammography and/or Breast Ultrasound Reports was developed, in the first instance and with the help of the EMIF Catalogue, which in the likeness to the developed by *Johnson et al.* [9] it's characterized by having section headers, consistent order of observations and terms for report reproduced from a controlled Lexicon, in our case the DICOM terminology. The integration of the Reports under this mechanism led to the creation of *MamoCatalogue*, where the introduction of the SR is performed according to the mechanism of *checklist*, which, as recommended by *Marcovici et al.* [29], allows the Radiologist is more focused on the important aspects of the images. 51 SR were introduced in the *MamoCatalogue*, that, a posteriori, were converted into DICOM-SR and integrated with the *Dicoogle* resulting in a DICOM-SR Repository, in line with the data bases developed in *Wangenheim quetsche et al.* [31], *García et al.* [32] *and Margolies et al.* [33] investigations.

The integration with the *Dicoogle* allowed the visualization of the Imaging study as a whole, watching Images and Reports on the same workstation, as described by *Noumeir* [15] and it allowed the realisation of *query and retrieve* operations to the data base.

	FT	SR	Differences	
	Mean (SD)		Mean (SD)	*P value*
Structure	3,86 (0,91)	2,84 (0,59)	1,02 (1,05)	0,042
Clarity and assertiveness	3,92 (0,90)	2,94 (0,50)	0,98 (0,97)	0,037
Diagnostic / Recommendations	4,16 (0,71)	3,22 (0,39)	0,94 (0,99)	0,045
Easiness of reading	3,86 (0,91)	2,84 (0,59)	1,02 (1,05)	0,042
	Ratio of evaluated answers with YES		*P value*	
Full reading	1,00	0,80	0,082	
Partially reading with BIRADS focus	0,16	0,20	0,569	
Ambiguity	0,16	0,34	0,078	

In addition, it is possible to study or withdraw elations of the population by statistical analysis operations. The constituted DICOM-SR Repository is the beginning of a data base, which once stronger, with the insertion of more studies in the context of the Breast Imaging, can play an important role in the areas of teaching, research and clinical decision support, making possible operations of *data mining*, as documented *by Garcia et al.* [34] and *Margolies et al.*[33]. In sensitive areas, as it is the case of Breast Cancer, in which early detections, effective screening and optimization of treatments have direct effects on the survival of patients [1, 2, 3] these systems take on a particular relevance for the specialists in the areas of treatment, teaching and scientific research, leading to optimization of the care for these patients[32]. The related data to the DICOM-SR can be used, not only in the improvement of the Imaging Reports, but also in the monitoring of critical and unexpected results and operations of correlation[35], where the optimization techniques, detection and screening of Breast Cancer are optimized[33].

The acceptance of the Radiologists and non-Radiologists by FT *vs*. SR was evaluated by implementing a Questionnaire that allowed evaluating the degree of satisfaction of Physicians regarding various aspects of the FT and SR. This analysis revealed divided opinions about the SR. *Schwartz et al.*[36] demonstrate in their study means of satisfaction of Clarity, which differ from those of this research. In the other hand, Johnson *et al.*[9] showed a decrease in the accuracy and integrity of the SR compared with the FT in its research, corroborating the results in discussion. The trend by the FT can arise from excessive simplification of the SR in the reporting of complex cases and the rigidity inherent to the SR, as described in the study by *Faggioni et al*.[37].

The statistical analysis performed by medical specialty does not demonstrate a trend so evident by the FT and, effectively, statistically significant differences are not found between the means of FT *vs.* SR satisfaction for the specialties of Gynaecology/Obstetrics and GP. Therefore, the communication of Results through the SR, between Radiologists and requesting Physicians (Gynaecology/Obstetrics and GP), is performed successfully. The opposite occurs with the Radiologists. *Krupinski et al*.[38] report that the Radiologists are most opposed to the non-traditional Reports, claiming that they never used the Reports and expressing its displeasure. In the *Barbosa et al.* investigation[6], 66.7% of the Radiologists just preferred the SR if adjustments to the reports were made. The dissatisfaction of the

Radiologists by the SR may be explained by the fear that they have to lose their professional autonomy and freedom with the inclusion of these documents in professional practice, as concluded *Faggioni et al.* [37] and *Bosmans et al.*[28]. In view of the obtained results on the acceptance of Physicians by the SR, strategies should be implemented for the acceptance of the same, especially with the Radiologists. These strategies can be, by involving the Radiologists in the creating process of the *Templates* as suggested by *Faggioni et al*.[37] and conducted *by Garcia et al.*[33]. In addition, it is important that the implementation of the SR will always be an ongoing process[7] and, to the majority of the surveyed professionals, this was the first contact with the SR.

During the research, some limitations were identified such as the manual process and something long inherent to the structure of the Reports with the *MamoCatalogue* and the heterogeneity of the sample, both in the number of Radiologists (28%) *vs.* non-Radiologists (72%), which is not in the same ratio, as in the age of surveyed.

6. Conclusion

This work implemented a DICOM-SR Repository, which is characterized as a searchable universe, where it is possible to study, consult and recover quickly data. This Repository may represent the beginning of a database in the area of Breast Imaging, where it is possible storing imaging studies and their Reports and conducting *query and retrieve* operations, including Imaging Reports, impractical tasks so far with traditional FT systems.

The Physicians evaluation of FT *vs.* SR showed that for the Gynaecology/Obstetrics and GP specialties the differences between the FT *vs*. SR are not significant, allowing to conclude a good acceptance of the SR by these professionals and a satisfactory communication of Results. The opposite occurs with Radiologists, who still are the most satisfied with the Structure, Diagnosis and FT Recommendations and considerer these Reports clearer and more assertive than SR. Thus, improvements should be promoted to the SR, with the Radiologists involvement, and acceptance strategies should be developed to these documents, particularly among Radiology specialists, promoting the global communication in the Medical community and the optimization of patients healthcare.

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