A neural network-enhanced methodology for the rapid establishment of local DRLs in interventional radiology: EVAR as a case example

Eleftherios Tzanis, John Damilakis *
Department of Medical Physics, School of Medicine, University of Crete, P.O. Box 2208, 71003 Heraklion, Crete, Greece

ARTICLE INFO
Keywords:
Diagnostic reference levels
Interventional radiology
Natural language processing
Endovascular aneurysm repair
Radiation protection

ABSTRACT
Purpose: To develop a neural network-enhanced workflow for the automatic and rapid establishment/update of local diagnostic reference levels (DRLs) in interventional radiology (IR) using endovascular aneurysm repair (EVAR) procedures as a case example.

Methods: Radiation dose reports were collected retrospectively for 46 consecutive EVAR procedures. These reports served as demonstrative data for the development of the proposed methodology. An algorithm was developed to receive multiple dose reports, automatically extract the kerma area product (KAP), air kerma (Ka,r), number of exposure images, and fluoroscopy time (FT) from each report and calculate the first, second, third quartiles as well as the maximum and minimum values of the extracted parameters. To extract the values of interest from the dose reports, Tesseract, an open-source optical character recognition (OCR) engine was employed. Furthermore, the accuracy and time efficiency of the proposed methodology were assessed. Specifically, the values extracted from the algorithm were compared with the ground truth values and the algorithm’s processing time was compared with the respective time needed to manually extract and process the values of interest.

Results: The OCR-based algorithm managed to correctly recognize 182 from the 184 target values, resulting in an accuracy of 99%. Moreover, the proposed pipeline reduced the processing time for the establishment of DRLs by 98%. DRL value for EVAR procedures, set as the third quartile of KAP was found to be 551 Gy·cm².

Conclusion: An accurate and time-efficient workflow was developed for the establishment of local DRLs in interventional radiology.

1. Introduction

The International Commission on Radiological Protection (ICRP) introduced [1] diagnostic reference levels (DRLs) in the 1990s as an optimization tool regarding radiation protection in diagnostic and interventional radiology. Since then, many other authorities and organizations such as the International Atomic Energy Agency (IAEA) and European Commission [2–6], suggest the development and use of DRLs for the optimization and evaluation of the applied protocols and methodologies.

Fluoroscopically guided interventions, such as endovascular aneurysm repair (EVAR), percutaneous transluminal angioplasty (PTA), stent placement, and embolization procedures have become increasingly common in everyday clinical practice. The use of fluoroscopy in these procedures provides valuable real-time imaging guidance, but it also presents the risk of exposure to considerable radiation doses [7–11]. Establishing DRLs for fluoroscopically guided interventions can help ensure that radiation exposure to patients and interventional radiologists is minimized while maintaining the image quality necessary for the procedure [12–14].

However, the establishment and frequent review of DRLs are time-consuming processes that require the collection of large volumes of data as well as the processing and statistical analysis of the collected data. These issues make the widespread establishment and use of DRLs in routine clinical practice challenging.

A considerable number of recent studies have demonstrated the efficacy of natural language processing (NLP) algorithms regarding data retrieval from text files, images, and medical reports [15–18]. NLP-based workflows allow the automatic and rapid extraction of valuable information from medical data. The aim of the current study was the utilization of an optical character recognition (OCR) algorithm for the development of a fully automated, time-efficient workflow for the

* Corresponding author.
E-mail address: john.damilakis@med.uoc.gr (J. Damilakis).

https://doi.org/10.1016/j.ejmp.2023.103140
Received 17 May 2023; Received in revised form 28 August 2023; Accepted 17 September 2023
Available online 21 September 2023
1120-1797/© 2023 Associazione Italiana di Fisica Medica e Sanitaria. Published by Elsevier Ltd. All rights reserved.
establishment/update of local DRLs in interventional radiology. EVAR procedures were used as a case example.

2. Materials and methods

2.1. Data

For the development and validation of the proposed methodology, data from EVAR procedures were collected and utilized. Specifically, radiation dose reports were collected retrospectively for 46 consecutive EVAR procedures. The reports were retrieved manually from our institution’s picture archiving and communication system (PACS) database and exported as image files. Data collection/processing was approved by the local ethics committee.

2.2. Fluoroscopic system

EVAR procedures were performed on an Azurion 7 B20 ClarityIQ (release 2.1, Philips Medical Systems). This biplane fluoroscopic system is equipped with a floor-mounted C-arm and a ceiling-suspended C-arm. The C-arm mounted on the floor incorporates a flat panel detector with a diagonal of 38 cm, 184 × 184 μm pixel dimensions, and pixel resolution of 2000 × 1688. The C-arm unit suspended on the ceiling consists of a flat panel detector with a 50 cm diagonal and 1920 × 1448 pixel

![Dose Report | ClarityIQ](image)

**Fig. 1.** A dose report for an EVAR procedure as it was exported from the fluoroscopic system.
resolution. Moreover, the fluoroscopic system incorporates a built-in ionization chamber for the determination of the kerma area product (KAP) and air kerma (Ka,r). Automatic exposure control system and pulsed fluoroscopy were activated during the procedures. After the termination of each procedure, the system automatically creates and exports the patient’s dose report (Fig. 1).

2.3. Algorithm

Scripting was performed with the python 3.8 programming language. A script was developed to receive multiple dose reports, extract the total KAP, total Ka,r, number of exposure images, and total fluoroscopy time (FT) from each report, and automatically calculate the first, second, third quartiles as well as the minimum and maximum values of the exposure parameters. Quartiles of the dose distribution can be used for the determination of DRLs for fluoroscopically guided procedures. Herein, the third quartile of KAP was used for the establishment of local DRLs.

Fig. 2 indicatively shows the algorithm’s pipeline. OpenCV [19] library was used to read and process the dose report images. Initially, the dose reports were transformed to 8-bit grayscale images. Each processed image was cropped to four sub-images. The sub-images contained the exposure parameters of interest (i.e. total KAP, total Ka,r, number of exposure images and total FT). The cropped images were resized and further processed to eliminate background noise. To automatically retrieve the values of interest from the cropped images, Tesseract [20,21] was employed. Tesseract is an open-source OCR engine. From version 4, it incorporates a long short-term memory (LSTM) neural network. Tesseract recognizes more than 100 languages, supports unicode (UTF-8) and can be used to extract text and numeric values from images [22–24]. OCR was performed through Tesseract for each of the sub-images. The extracted values were used from the algorithm to determine the first, second, third quartiles as well as the minimum and maximum values of exposure parameters. When the processing was finished the algorithm exported the results as an excel file. Moreover, histograms with the distribution of the exposure parameters were created with the matplotlib library [25] and exported as image files.

2.4. Algorithm’s efficiency

To validate the efficacy of the optical character recognition engine, we manually created an excel file with the ground truth values of KAP, Ka,r, number of exposure images and FT. These values were compared with the corresponding values which were exported from the algorithm. Moreover, to determine the time efficiency of the proposed workflow, we compared the time needed to manually extract the parameters of interest and determine the local DRLs with the corresponding time that the algorithm needed.

2.5. Statistical analysis

Statistical analysis was carried out utilizing SciPy [26] python library. To determine the correlation between exposure parameters, Pearson’s correlation test was used. Statistical significance was presumed when p-value was <0.05.

3. Results

Tesseract was employed to retrieve from each of the 46 EVAR dose reports the total KAP, total Ka,r, number of exposure images and total FT. From the 184 target values, the OCR algorithm managed to correctly recognize 182. This results in an accuracy of 99%. In two specific instances, the OCR algorithm was unable to successfully extract values. Specifically, it failed to retrieve the number of images (171) from one
The establishment of DRLs for all types of procedures performed in an interventional radiology department requires the collection and processing of large volumes of data. These processes are time-consuming and require appropriate scientific background and specialized knowledge. Other important difficulties are the lack of a standardized methodology for the establishment of DRLs and the insufficient training of personnel regarding the set-up, usage, and review of DRLs. With its recent publication [13], the EuroSafe Imaging ‘Clinical DRLs’ working group attempts to address these issues. Their work presents the current limitations regarding the development and use of DRLs and gives useful guidelines regarding the establishment of local DRLs.

NLP algorithms and machine learning models have recently been used in numerous studies for the automatic extraction of data from medical reports [15-18]. However, the DRLs domain has not yet benefited from such innovative technologies. To the best of our knowledge, this is the first study that utilizes an OCR engine which is based on an LSTM neural network for the automatic establishment of DRLs. The developed workflow is accurate and time-efficient. The algorithm preprocesses the imported dose reports, extracts the exposure parameters of interest, and calculates DRL values in seconds, without requiring any interaction with the user. Although commercially available dose management systems can be used for the establishment and review of DRLs, these systems may not be available to hospitals or institutions due to high cost or may not be suitable for older angiographic systems. Our methodology was developed using open-source libraries and can be readily adapted to various angiographic systems with minimal adjustments. These characteristics render our methodology a cost-effective and time- and money-saving solution that can be implemented by hospitals or institutions for the establishment/update of DRLs pertaining to interventional radiology procedures.

A limited number of studies present DRL values for EVAR procedures [8,14,27]. Tuthill et al. [8] conducted a multicenter study for the establishment of DRLs regarding EVAR procedures. They collected data for 180 EVAR procedures from five different European institutions. The mean KAP values reported in their study range from 43.4 Gy·cm² to 319.0 Gy·cm² while the overall DRL value was found 158.5 Gy·cm². Rial et al. [27] established national DRLs for EVAR procedures in Spain. They collected data from 165 EVAR procedures performed using X-ray mobile systems as well as 123 EVAR procedures conducted in hybrid rooms. Based on their analysis, the proposed DRL value for hybrid rooms was determined to be 278 Gy·cm² while for mobile X-ray systems, the recommended DRL value was found to be 87 Gy·cm². The DRL value reported herein is higher than the respective values presented in the literature. Nevertheless, conducting a direct comparison is inherently challenging, particularly in fluoroscopically guided procedures, due to the multitude of factors influencing patient radiation exposure. These factors encompass patient size and anatomy, procedure complexity, applied protocols, the specific angiographic system employed, as well as the experience level of the interventional radiologist.

5. Limitations

For the development and validation of the algorithm, dose reports for a single type of fluoroscopically guided procedures were used. However, the algorithm was developed to extract specific exposure parameters from dose reports. As the structure of the exported dose reports is the same for all types of procedures performed in our angiographic system, the usage of the proposed pipeline is not limited to EVAR. The developed workflow was applied to a specific system. However, the proposed methodology can easily be extended to other systems by adapting the preprocessing to the actual form of dose reports derived from these systems. Furthermore, it is worth noting that the manual collection of the dose reports from the PACS database could pose a limitation of the presented methodology due to its time-consuming nature. Future studies could explore the feasibility of automating this data collection step to enhance overall process efficiency.

6. Conclusion

In the current study, an OCR-based algorithm was developed for the establishment of local DRLs in interventional radiology. The proposed workflow is time-efficient, accurate and it does not require extensive interaction with the user. These characteristics make it a useful tool for the automatic and rapid establishment/update of local DRLs regarding fluoroscopically guided procedures. Additionally, the developed methodology offers the potential for routine monitoring of compliance with established DRLs.

7. Data and code

The data used for the current study and the developed code are available in the supplementary material. Moreover, readers can execute the developed code and reproduce the reported results through the following google colab notebook: https://colab.research.google.com/drive/1kodOqNIp6LyDfJh4jgJsm4tIKgzaWam6t?usp=sharing.

Conflict of interest

None.

Formatting of funding sources

The current study has received funding from the research project “Patient dosimetry in computed tomography, interventional radiology and mammography” (KA10697).

Table 1

<table>
<thead>
<tr>
<th>Quartiles of KAP, Ka,r, FT, exposure images.</th>
<th>KAP (Gy·cm²)</th>
<th>Ka,r (mGy)</th>
<th>FT (min)</th>
<th>Exposure images</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st quartile</td>
<td>228.5</td>
<td>723.8</td>
<td>15.4</td>
<td>108</td>
</tr>
<tr>
<td>2nd quartile</td>
<td>343.0</td>
<td>1292.5</td>
<td>19.2</td>
<td>172</td>
</tr>
<tr>
<td>3rd quartile</td>
<td>551.0</td>
<td>1870.3</td>
<td>24.9</td>
<td>280</td>
</tr>
<tr>
<td>IQR</td>
<td>322.5</td>
<td>1146.5</td>
<td>9.5</td>
<td>172.3</td>
</tr>
<tr>
<td>Min</td>
<td>89.7</td>
<td>276</td>
<td>10.9</td>
<td>85</td>
</tr>
<tr>
<td>Max</td>
<td>2235</td>
<td>11,635</td>
<td>139</td>
<td>500</td>
</tr>
</tbody>
</table>

IQR = interquartile range.
Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jejmip.2023.103140.

References