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Discrepancy rate and clinical impact of preliminary reports from radiology residents

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ABSTRACT

Background: Residents usually cover night and weekend shifts issuing the preliminary reading of radiological studies in university hospitals. This is essential to strengthening decision-making skills when facing complex cases independently. However, there should be a balance between patient safety and academic experience since some concern has been expressed about the accuracy of the interpretations generated by trainees. This work aims to evaluate and characterize the discrepancies in preliminary reports issued by radiology residents.
Material and methods: Radiologists filled out a questionnaire to evaluate preliminary reports of trainees considering diagnosis, findings description, clinical approach changes, and critical findings. Analysis was performed considering modality, imaging type, body part, and resident academic year. A Chi-square test with a significance level α of 0.05 was used to make group comparisons.
Results: A total of 9072 studies were reviewed. Major and minor overall discrepancy rates were 1.7% and 8.3%, respectively. Minor discrepancy rate, findings description, and critical findings identification improved with increasing academic year, both overall and by modality. Discrepancy rates were lower for CT than MR and neuroimaging than for body-imaging studies. The highest major and minor discrepancy rates as abdomen/pelvis CT and lumbar-spine MR, respectively. Two percent of reports presented discrepancies that could generate a medical approach change.
Conclusion: Discrepancy rates are low and comparable with those reported in the literature. These rates tend to improve as the resident's academic year increases. Our results suggest that radiology residents' coverage of night shifts and weekends is a practice that benefits the educational process without negatively impacting patient safety.

1. Background

In the Radiology department of university healthcare centers, night and weekend shifts are usually covered by radiology residents, who oversee issuing the preliminary reading of radiological studies, subsequently reviewed by a radiologist within the next business

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hour [1–9]. These scenarios are essential during the training process of future radiologists to strengthen decision-making skills when facing complex cases independently [1,3–9].

Nevertheless, with the progressive increase in quantity and the complexity of diagnostic imaging studies, educational programs should seek a balance between patient care and the academic experience of residents since some concern has been expressed about the diagnostic accuracy of the interpretations generated by radiology trainees [3]. For this reason, healthcare institutions should implement quality control programs that allow continuous and systematic monitoring of preliminary radiological reports to Ref. [1] guarantee adequate and timely interpretations of all imaging studies and [2] identify opportunities for improvement in medical care and academic processes.

Previous studies have shown discrepancy rates between the resident preliminary interpretation and the final radiologist report between 1.4% and 29.9%, mainly in magnetic resonance (MRI) and computed tomography (CT) imaging studies [1–17]. This rate tends to increase in images of high complexity, such as CT abdomen, CT angiography, and brain MRA studies, where a discrepancy rate has been reported between 12.1% and 13.6% [4,17,18]. Furthermore, the literature shows that cases of false negatives are more common than false positives; that is, it is more common to miss an imaging finding than to misinterpret one [1,19].

One of the main concerns of a discrepancy in this context is the clinical impact on the patient, either due to the lack of opportunity in the therapeutic approach or exposure to unnecessary procedures because of radiological interpretation. Mellnick et al. reported that 23.2% of the patients had already been discharged when the discrepancy was identified in the radiological study [15], while Friedman et al. reported that 67.9% of patients had already been transferred from the emergency department at the time of notification of the discrepancy [19]. The main clinical impact reported in the literature was a change in referral to another clinical subspecialty (57.1%), followed by the alteration in clinical (25.0%) and surgical (21.4%) management, while, from the perspective of emergency physicians, the main impact was an increase in morbidity and prolonged hospitalization, with no alteration in mortality or long-term outcome [19].

On the other hand, there are contradictory results in the literature regarding the correlation between the academic level of the resident and the discrepancies rate. While Cooper et al. reported that there are no differences in the rate of discrepancy between radiology residents of different academic years [20], some authors have reported that radiology trainees in the first residence years have a significantly higher rate of discrepancies [17,18,21,22].

The aim of this study is to evaluate the discrepancies between the preliminary report of the radiology resident and the final interpretation of the radiologist in MRI and CT studies, considering the diagnosis, findings description, critical findings identification, and if the discrepancy generated a change in the clinical approach of patients. In addition, the clinical outcome of all cases was assessed in order to evaluate the clinical impact of such discrepancies.

2. Materials and methods

The radiology department of our institution has 24-h coverage for ultrasound, radiography, computed tomography, and magnetic resonance studies. On regular business days between 7 a.m. and 5 p.m., the radiology medical staff carry out the interpretation of the studies, while the radiology residents are responsible for providing the preliminary interpretation of CT and MRI studies performed during the evening hours and on weekends. The next business day, the radiologist of the corresponding assignment reviews the preliminary reports with the resident, making the respective adjustments and feedback as an educational process, and officially validating the radiological report.

The radiology residency program consists of four years, the first year includes four rotations which are neuro-CT and -MRI, body CT, ultrasound, and x-ray: all focused-on emergency techniques and pathologies. Within the training process, radiology residents begin to take shifts during the second year of residence.

2.1. Evaluation of preliminary reports

During the review of the CT and MRI studies, the radiologist fills out a questionnaire of four variables within the reading task:

1. Identification of the correct diagnosis (Yes, No, Partial).
2. Correct description of the findings (Yes, No, Partial).
3. Change in patient management associated with inadequate or incorrect identification/description of imaging findings according to the criteria of the reviewing radiologist (Yes, No).
4. Presence of a radiological finding is considered critical (Yes, No).

A minor discrepancy was considered when the correct diagnosis variable was marked with the “Partial” option and a major discrepancy when the “No” option was checked. The list of radiological diagnoses considered critical is the same as that previously described [23].

All patients marked as “Yes” in the Change in patient management field were assessed. A review of the electronic medical records in the Hospital Information System (HIS), of each patient was performed, evaluating the admission episode related to the radiological report and analyzing the outcomes and possible changes in the treatment approach. The person evaluating the clinical outcomes is not a radiologist but a clinically oriented physician; it focuses on evaluating the patient’s follow-up, outcomes, and whether this approach change had a deleterious outcome on the patient.

2.2. Data analysis and statistical methods

All data related to study date, modality and imaging type, body part, contrast medium usage, and radiology resident full name were extracted from the Radiological Information System; resident name was used to identify the academic year of the resident. Furthermore, medical records were extracted from the Hospital Information System to review all cases which were marked as "Yes" in the change in patient management variable to evaluate the clinical outcome of the patient.

The groups were compared with a chi-square test, with a significance level α of 0.05, with adjustment of the significance level for multiple comparisons using the Bonferroni method as necessary. The error bars shown for the percentages in the graphs were tabulated using the Wald method described by Agresti and Coull [24].

This study was approved by the institutional ethics committee, the used of informed consent was waived due to the retrospective nature of the study.

3. Results

Between January and June 2021, 9072 forms were completed during the delivery of the residents' shift, 5488 (60.5%) of emergency studies, 2038 (22.5%) of hospitalized patients, and 1546 (17.0%) of outpatient studies. Table 1 details the number of studies evaluated by year of residence and modality, observing a statistically significant association between the year of residence and the distribution by modality ($p < 0.01$).

3.1. Overall discrepancy rates

In general, 90.0% of imaging studies interpreted by radiology residents included the main diagnosis, while in 8.3% it was partially identified, and in 1.7% the main diagnosis was not identified. The imaging findings were correctly and fully described in 86.5% of preliminary reports, partially described in 12.1%, and incomplete in 1.4%. Table 2 shows the detailed results by residence year; a statistically significant association between the residence year and correct diagnosis identification ($p < 0.01$), and correct findings description ($p = 0.015$) was observed. There was no statistically significant association between residence year and clinical management alteration ($p = 0.981$).

In terms of modality, a statistically significant association was observed between the correct identification and description of the main diagnosis and the modality, with higher performance in CT studies ($p < 0.01$) (Table 3). Compared with MRI, the percentage of studies whose discrepancy had the potential to generate a change in the clinical management was less statistically significant in CT ($p < 0.01$) (Table 3)..

Regarding the academic level of the resident, an association was found between the minor discrepancy rate and the residence year for CT studies (RY2 = 8.76%, RY3 = 6.79%, RY4 = 4.61%). Despite not being statistically significant, this trend is also observed for MR studies, as shown in Fig. 1 b (RY2 = 13.72%, RY3 = 11.22%, RY4 = 10.34%). Furthermore, as pointed out before, clinical management change and major discrepancy rate are statistically significantly lower in CT and neuro studies compared with MR and body studies; nevertheless, they are not statistically significantly associated with radiology residence year by modality or body part (Fig. 1 a., 1.c, and 1.d).

Table 5 shows the results of the 10 most frequent studies, which represent 89.6% of the total studies analyzed. In general, the studies that presented the highest rates of major discrepancy were abdomen/pelvis CT (7.1%), followed by brain MRA (4.8%) and chest CT (4.7%); while the highest rates of minor discrepancies were in simple lumbar spine MRI studies (15.4%), followed by abdomen/pelvis CT (11.3%) and chest CT (11.0%). On the other hand, the reports whose discrepancies were significant and had the potential to generate a change in clinical management in the patient were mainly from chest CT studies (7.1%), abdomen/pelvis CT (6.3%), and lumbar spine MRI (5.1%). The study that involved the most critical diagnoses was carotid and cerebral arteries CT (30.7%), which presents a low rate of minor (5.5%) and major (1.0%) discrepancies compared to the rest of the studies..

3.2. Impact on the clinical outcome of patients

According to the radiologist criteria, 2.0% (n = 184) of the reviewed preliminary reports presented minor or major discrepancies that could generate a change in the medical management of patients, 114 (62.0%) of emergency studies, 39 (21.2%) of hospitalized patients, and 31 (16.8%) of outpatient studies. Of all these, 88.1% did not generate any impact on the patient's clinical approach, while in 8.6% of the cases (all emergencies) there was a delay in care related to waiting for the final radiological report the next day: patient

Table 1
Number of studies evaluated by year of residence (RY) and modality.

Residence Year	Modality		
	CT	MR	TOTAL
RY2	2693 (77,1%)	802 (22,9%)	3495 (38,5%)
RY3	3344 (78,6%)	909 (21,4%)	4253 (46,9%)
RY4	976 (73,7%)	348 (26,3%)	1324 (14,6%)
TOTAL	7013 (77,3%)	2059 (22,7%)	9072 (100%)

Table 2
Detailed results by year of residence (RY).

Resident year	Correct Diagnosis			Correct Findings Description			Clinical Management Alteration (Yes)
	Yes	Partially	No	Yes	Partially	No	
RY2	3095 (88.6%)	346 (9.9%)	54 (1.5%)	2971 (85.0%)	462 (13.2%)	62 (1.8%)	72 (2.1%)
RY3	3852 (90.6%)	329 (7.7%)	72 (1.7%)	3710 (87.2%)	490 (11.5%)	53 (1.2%)	85 (2.0%)
RY4	1218 (92.0%)	81 (6.1%)	25 (1.9%)	1164 (87.9%)	145 (11.0%)	15 (1.1%)	27 (2.0%)

Discrepancy rates by modality, body part and type of study.

Table 3
Detailed results by modality.

Modality	Correct Diagnosis			Correct Description			Clinical Management Alteration (Yes)
	Yes	Partial	No	Yes	Partially	No	
CT	6407 (91.4%)	508 (7.2%)	98 (1.4%)	6165 (87.9%)	766 (10.9%)	82 (1.2%)	129 (1.8%)
MR	1758 (85.4%)	248 (12.0%)	53 (2.6%)	1680 (81.6%)	331 (16.1%)	48 (2.3%)	55 (2.7%)

On the other hand, in terms of the body part, a statistically significant association was observed between the correct identification and description of the main diagnosis and the body part, with performance being higher in neuro studies ($p < 0.01$) (Table 4). Likewise, the percentage of studies whose discrepancy had the potential to generate a behavior change was statistically significantly higher in body studies ($p < 0.01$) (Table 4).

Table 4
Detailed results by body part.

Body part	Correct Diagnosis			Correct Description			Clinical Management Alteration (Yes)
	Yes	Partial	No	Yes	Partially	No	
Body	562 (83.4%)	72 (10.7%)	40 (5.9%)	562 (83.4%)	84 (12.5%)	28 (4.2%)	50 (7.4%)
Neuro	7603 (90.5%)	684 (8.1%)	111 (1.3%)	7283 (86.7%)	1013 (12.1%)	102 (1.2%)	134 (1.6%)

was discharged in 1.3% of cases, who had to be called to re-consult for emergencies, 1.3% of the patients were already in surgery at the time of report generation, and one patient died of a vital emergency before the radiological report was generated (0.7%).

3.3. Radiological critical findings

On the other hand, 15.5% (n = 1407) of the interpreted studies involved a critical radiological finding, of which 2.4% (n = 33) were not reported in the preliminary report (RY2: n = 19, 57.6%; RY3: n = 10, 30.3%; RY4: n = 4, 12.1%), with statistically significant association between the year of residence and the correct identification of the critical finding ($p = 0.035$).

4. Discussion

Interpretations of diagnostic imaging studies by radiology residents may raise concerns for other specialists because the trainees' lack of experience may affect the patients' clinical outcomes. At our institution, we have developed a program to monitor the performance of residents in order to evaluate minor and major discrepancies, omission of critical diagnoses, and possible changes in behavior due to improper imaging interpretation. This work describes our academic follow-up experience of radiology residents' shifts in their second, third, and fourth years of residence.

Our results demonstrated that the rate of minor and major discrepancies in the preliminary reports were 8.3% and 1.7%, respectively, within the range of values previously published in the literature (Table 7). Regarding body parts, major and minor discrepancy rates were 1.3% and 8.1% for neuroimaging studies and 5.9% and 10.7% for body imaging studies. These values are similar to those reported previously [20–22]. The difference may be related to three main factors. First, neuroimaging studies are often most ordered and thus are most frequently interpreted by radiology trainees. For instance, in this study, neuroimaging accounted for 92.6% of the total studies interpreted by residents during shifts. Second, the curriculum includes two months of neuroradiology and two months of body imaging in the first year of residence. However, it should be considered that body imaging explores a much wider range of the human body, including multiple asymmetric anatomical structures, and there is a broader spectrum of pathologies to evaluate. Hence, one could argue that adjusting the curriculum to increase body image study time could decrease the rate of discrepancies. Third, in our institution, the development of structured reports and diagnostic algorithms in neuroimaging has been addressed more broadly; thus, residents have more tools when reading a neuroimaging study than body imaging.

In the analysis by modality, a lower value of major and minor discrepancy rates was observed in CT studies compared to MRI. This finding, previously reported by other authors in the literature, may be related to the complexity of interpreting an MRI study with more sequences and more morphological, dynamic, and functional information on anatomical structures than CT studies [4,17,19,22].

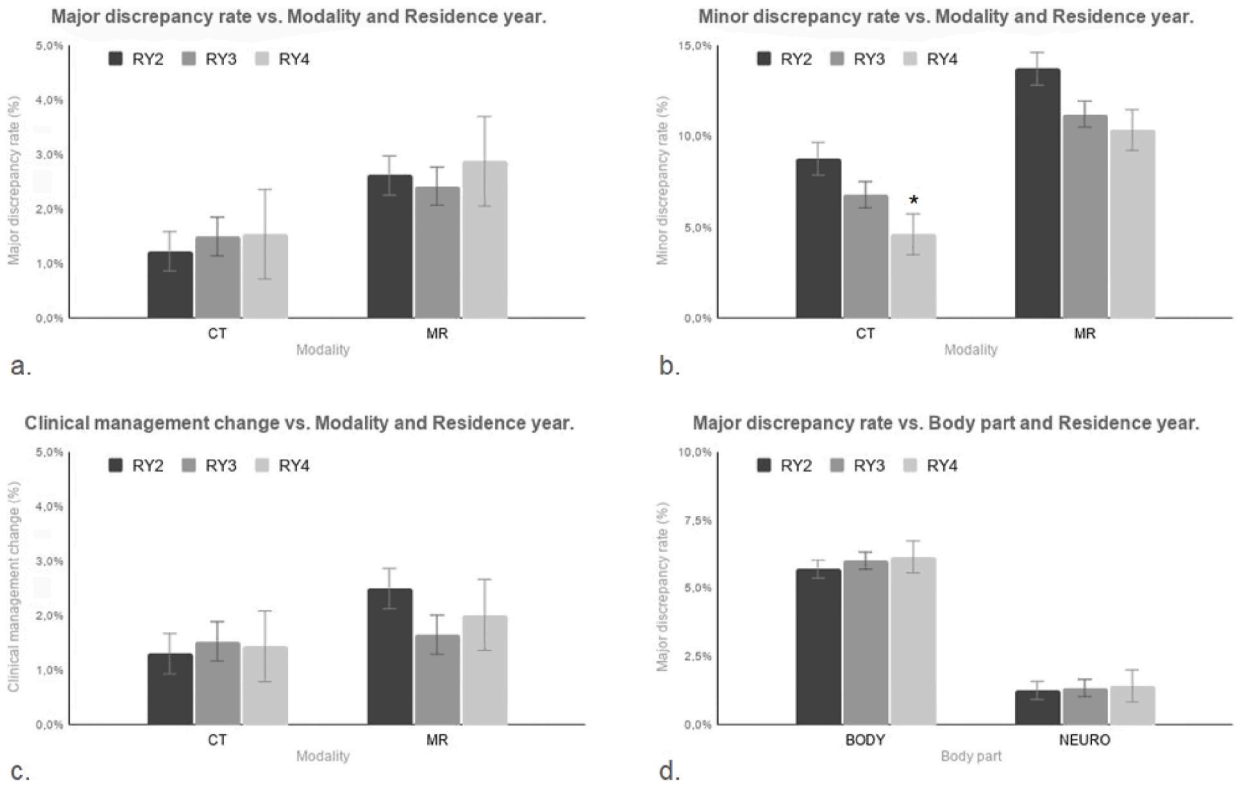

Fig. 1. Major discrepancy rate (a), minor (b), change in clinical behavior (c) by modality and year of residence, and major discrepancy rate by body part and year of residence (d). (*) denotes statistically significant difference between RY2 and RY4.

Table 5
Ten most frequent studies.

Imaging procedure	n	%	Minor discrepancy	Major discrepancy	Clinical Management Alteration	Critical finding
Brain CT	4404	48.5%	6.5%	0.7%	1.1%	15.0%
Brain MRI	1404	15.5%	10.7%	2.7%	2.7%	12.0%
Whole Spine CT	941	10.4%	6.3%	1.3%	1.5%	17.3%
Face/Sinus CT	368	4.1%	9.0%	0.5%	0.8%	4.4%
Brain Arteries CT	293	3.2%	5.5%	1.0%	2.4%	30.7%
Abdomen/Pelvis CT	240	2.7%	11.3%	7.1%	6.3%	15.0%
Brain MRA	147	1.6%	6.8%	4.8%	2.7%	17.7%
Chest CT	127	1.4%	11.0%	4.7%	7.1%	9.5%
Lumbar Spine MRI	117	1.3%	15.4%	3.4%	5.1%	8.6%
Enhanced Brain CT	86	1.0%	10.5%	0.0%	1.2%	9.3%

Of all the studies included, 7848 (86.51%) were non-enhanced contrast studies, and 1224 (13.49) were contrast-enhanced. A statistically significant association between the use of contrast agents and the minor and major discrepancy rates ($p < 0.01$) was observed, being lower in non-enhanced contrast studies. Moreover, a better description of the findings ($p < 0.01$) and a lower rate of clinical management alteration ($p < 0.01$) were observed in the non-enhanced studies (Table 6).

Table 6
Detailed results by modality.

Contrast agent	Correct Diagnosis			Correct Description			Clinical Management Alteration (Yes)
	Yes	Partial	No	Yes	Partially	No	
Yes	1043 (87.5%)	125 (10.5%)	24 (2.0%)	989 (83.0%)	180 (15.1%)	23 (1.9%)	42 (3.5%)
No	7122 (90.4%)	631 (8.0%)	127 (1.6%)	6856 (87.0%)	917 (11.6%)	107 (1.4%)	142 (1.8%)

Table 7
* Overall discrepance rate.

Author	n	Major discrepance rate (%)	Minor discrepance rate (%)
Weinberg et al.	416413	1.7	Not reported
Mellnick et al.	153420	Not reported	1.4*
Cooper et al.	141381	1.0	3.3
Current	9072	1.7	8.3
Bruni et al.	5666	1.2	7.2
Stevens et al.	2830	0.4	1.6
Bechtold et al.	694	2.7	4.9
Wechsler et al.	598	1.2	6.5
Carney et al.	513 (CT)	1.0	5.4
Yoon et al.	512	Not reported	29.9
Wysoki et al.	419	1.7	2.6
Filippi et al.	361	4.2	2.2

Moreover, as the amount of MRI studies performed is usually significantly lower than CT studies, one could assert that obtaining experience in reading and interpreting an MRI would take more time than CT images [17]. Accordingly, as noticed in Fig. 1, although there are no changes in the major discrepancy rates, the minor discrepancy rate for MRI studies tends to decrease as the residence year increases. These arguments, together with the extensive and complex anatomical structures explored during the body studies, could also explain the high discrepancy rates in studies such as abdomen/pelvis CT, brain MRA, and spine MRI, like that reported by Ruchman et al. Friedman et al., and Bruni et al. [1,19,22].

There are contradictory results in the literature regarding the correlation between the academic level of the resident and the discrepancies rate. While Cooper et al. reported no differences in the rate of discrepancy between radiology residents of different academic years [20], some authors have reported that radiology trainees in the first residence years have a significantly higher rate of discrepancies [17,18,21]. Our results support these latter findings; we found a statistically significant association between the resident's academic year and the correct identification of the principal diagnosis and the adequate description of the findings, related to a decrease in the rate of discrepancies.

Changes in clinical approach related to the discrepancy in preliminary reports of radiology studies are one of the major concerns in this context as they may be related to alteration in medical or surgical management, increase in morbidity, and prolonged hospitalization [15,19]. In our experience, the rate of change in the clinical approach of patients was low (2%), and we were able to determine that major and minor discrepancies did not lead to an increase in morbidity of patients, or their hospital stay. The main impact on the patient outcome was an increase in the time for decision-making in the clinical approach due to a delay in the final report. Moreover, there was no statistically significant association between the resident's academic year and the rate of change in clinical behavior due to inadequate interpretation of the images. Together with what has been reported so far in the literature, these findings suggest that the second year of residence is a safe and good starting point for radiology trainees to individually confront reading, interpreting, and making decisions in the diagnostic approach of imaging studies [1,3].

The Joint Commission considers timely reporting of critical findings as one of the main patient safety goals [25]. Delays in their communication are strongly related to delayed treatment initiation and death [26]. Although only 0.36% of all studies presented a critical diagnosis that was not included in the preliminary report by the radiology resident, a statistically significant association was observed between the year of residence and the rate of unreported critical diagnoses. This is a significant issue in a diagnostic unit. Several technological and academic strategies have been implemented in our hospital to address the need to decrease the notification times of critical findings, engaging technologists, nurses, residents, and radiologists [23].

During the design and implementation of this strategy, we addressed several factors previously described by other authors to improve the data recollection and objectify the results and conclusions [4,20]. First, we carried out general training for all radiologists who assess shifts preliminary reports as part of their daily duties, explaining each variable and possible option. Second, we encouraged radiologists to fill out the form always and not only when there was a discrepancy. Third, residents encounter the same complexity of studies during their shift, regardless of their year of residence.

This study has certain limitations. First, although we consider the sample sufficient, it is significantly smaller than other studies. Second, the gold standard was the radiologist's final interpretation without peer review or follow-up over time. Some authors suggest that this could impact the results [20,21], as the final interpretations may be incorrect or miss relevant diagnoses. It is also important to mention that in the emergency department, patients are often uncooperative, and sometimes the examination quality is affected by motion artifacts. Although the definition of a minor or major discrepancy was discussed and defined in conjunction with the medical group of radiologists, this concept can be widely debated and differ from that described by other authors in the literature.

5. Conclusion

The discrepancy rates observed in our experience are low and comparable with those reported in the literature. Clinical management changes, major and minor discrepancy rates, as well as correct findings description and critical finding identification tend to improve as the resident's academic year increases. Consequently, our results suggest that the coverage by radiology residents of night shifts and weekends is a practice that benefits the educational process without negatively impacting patient safety. However,

educational programs that integrate practices in healthcare institutions should implement active surveillance strategies to monitor preliminary reports' performance and diagnostic accuracy that allow timely identification of whether any process needs to be adjusted or reinforced, both from an academic and clinical perspective.

Ethical approval and informed consent

This study was reviewed and approved. Following our institutional guidelines, all protected health information was removed, and individual patient consent was not required for the analysis.

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Author contribution statement

JFOZ: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.
VMQ: Analyzed and interpreted the data; Performed the experiments; Wrote the paper.
AMGS: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data; Analyzed and interpreted the data; Wrote the paper.

Data availability statement

Data will be made available on request.

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.

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