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Research Article

Does a new MRI on-call service improve the timely imaging for suspected cauda equina syndrome?

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ABSTRACT

Introduction: Cauda equina syndrome (CES) develops due to compression of cauda equina nerve roots and requires urgent diagnosis, preferably using MRI. This will allow timely intervention to prevent irreversible neurological problems. On-call services can potentially reduce time taken to diagnose CES outside of standard operational hours. Most acute hospitals in the UK do not have on-call provisions for CES. This study therefore assessed whether introducing a short period of on-call service at an acute hospital significantly reduced the time in diagnosing CES. This can form the decision for future operational changes with possible replication in similar settings.

Methods: The study was retrospective, comparing MRI exam time between the 12 months prior to the introduction of the on-call service and the 12 months post-introduction. One hundred sixteen patients with suspected CES during each timepoint were randomly sampled and data were analysed using Mann Whitney U, Kruskal-Wallis and chi-squared tests.

Results: Average MRI examination time (from request to report) was reduced by 0.7 h in the post-on-call timepoint compared to the pre-on-call timepoint, but this was not statistically significant ($U = 6558.0$, $p = 0.739$). However, for patients referred during the on-call period (19.30 to 22.00), examination time was reduced by 14.2 h (over 70%) in the post on-call timepoint compared to the corresponding period in the pre on-call timepoint. Also, grouping data by referral periods, there was a statistically significant difference between the two timepoints ($H = 74.5$, d.$f = 5$, $p < 0.001$). All the requests received during the on-call hours of the post on-call timepoint were completed within 24 h which was above the 95% target while only 85% completion was achieved in the corresponding period of the pre on-call timepoint. However, this difference was not statistically significant ($\chi 2$ (5) =8.4, $p = 0.137$)

Conclusion: This study demonstrated that though the short period of on-call reduced the overall MRI examination time for CES slightly, the reduction was not statistically significant.

RÉSUMÉ

Introduction: Le syndrome de la queue de cheval (SQC) se développe en raison d'une compression des racines nerveuses de la queue de cheval et nécessite un diagnostic urgent, de préférence à l'aide d'une IRM. Cela permettra une intervention rapide afin d'éviter des problèmes neurologiques irréversibles. Les services de garde peuvent potentiellement réduire le temps nécessaire au diagnostic du SQC en dehors des heures d'ouverture normales. La plupart des hôpitaux de soins aigus au Royaume-Uni ne disposent pas de services de garde pour le SQC. Cette étude a donc évalué si la mise en place d'un service de garde de courte durée dans un hôpital de soins aigus réduisait de manière significative le temps nécessaire au diagnostic du SQC. Cela peut servir de base à la décision de changements opérationnels futurs, avec une possible reproduction dans des contextes similaires.

Méthodologie: Il s'agit d'une étude rétrospective comparant la durée des examens IRM entre les 12 mois précédant la mise en place du service de garde et les 12 mois suivant cette mise en place. 116 patients suspectés de SQC à chaque période ont été sélectionnés de manière aléatoire et les données ont été analysées à l'aide des tests de Mann Whitney U, de Kruskal-Wallis et du chi carré.

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Ethical approval: Ethical approval for the study was obtained from the relevant department at the NHS trust responsible for the study hospital; reference number FXP-56 and registered with the relevant ethics department at a University in the UK; reference ETH2122-0882.

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Résultats: La durée moyenne de l'examen IRM (de la demande au rapport) a été réduite de 0,7 heure après la période de garde par rapport à la période précédant la garde, mais cette différence n'était pas statistiquement significative (U = 6558,0, p = 0,739). Cependant, pour les patients référés pendant la période de garde (19 h 30 à 22 h 00), la durée de l'examen a été réduite de 14,2 heures (plus de 70%) après le début de la garde par rapport à la période correspondante avant le début de la garde. De plus, en regroupant les données par période d'orientation, il y avait une différence statistiquement significative entre les deux moments (H = 74,5, d. f = 5, p < 0,001). Toutes les demandes reçues pendant les heures de garde après la période de garde ont été traitées dans les 24 heures, ce qui était supérieur à l'objectif de 95%, alors que seulement 85% des demandes ont été traitées pendant la période correspondante avant la période de garde. Toutefois, cette différence n'était pas statistiquement significative ($\chi 2$ (5) = 8,4, p = 0,137).

Conclusion: Cette étude a démontré que, bien que la courte période de garde ait légèrement réduit la durée globale des examens IRM pour le SQC, cette réduction n'était pas statistiquement significative.

Keywords: Cauda equina syndrome; MRI; On-call; Diagnosis; Examination time

Introduction

Cauda equina syndrome (CES) is a rare but serious condition caused by compression of the cauda equina (CE) nerve roots, which can result in permanent paralysis, and loss of bowel, bladder, and sexual functions if not promptly treated [1,2]. A bundle of descending nerve roots from the second lumbar nerve root to the coccygeal nerve roots are referred to as cauda equina [3,4]. According to Marieb and Keller [5], damage to these nerves or its branches leads to loss of sensation and flaccid paralysis of the area of the body served.

The treatment for CES is surgical decompression [6], but literature [6–9] suggests variations in timing of surgery. The British Medical Journal (BMJ) best practice [10] recommended surgery within 48 h from symptom onset.

MRI is currently the gold standard investigation for diagnosing CES, and it must be undertaken as an emergency where CES is suspected [11,12]. For imaging disc herniations (one of the causes of CES), MRI has a relatively high sensitivity (80.9%) and specificity (81.0%) compared to CT, which has a sensitivity of 81.3% and specificity of 77.1% and Myelography with a sensitivity of 75.7% and specificity of 76.5% [13]. Moreover, MRI is preferred over other imaging modalities for the diagnosis of CES because it does not use ionising radiation like CT and non-invasive like myelography but has excellent visualising capacities, especially for soft tissues [13,14].

Until recently, there was no UK nationwide agreement on timing of MRI for diagnosing CES and the National Institute for Health and Care Excellence (NICE) has no guideline specifically on CES [12]. The guidelines issued by the Society of British Neurological Surgeons (SBNS) and the British Association of Spinal Surgeons (BASS) [15] did not specify any time frame for imaging suspected CES. Besides, the terms 'urgent scan' and 'emergency scan' are used interchangeably, leading to varying time frames for MRI scans across the country [12]. The implications of this ambiguity and lack of consensus are variations in timings for CES diagnosis, surgical interventions and possibly clinical outcomes across the country. To mitigate this situation and bring clarity, the Royal College of Radiologists (RCR) [16] and Getting It Right First Time (GIRFT) [17] recommended MRI scan for patients with suspected CES as soon as possible and within 4 h of request to radiology department.

At the study hospital, a local rule/protocol was established that at least 95% of patients with suspected CES/metastatic spinal cord compressions (MSCC) must undergo MRI scans with reports produced within 24 h of the requests. To ensure compliance and therefore improve the timely diagnosis of CES, 2.5 h on-call service was introduced in July 2021.This extended the MRI service including imaging suspected CES/MSCC from 12 h to 14.5 h daily with the additional 2.5 h only for CES/MSCC. In general, requests for diagnostic imaging out of hours or during on-calls are known to be justified because positive diagnosis can change management of patients [18–20].

Within the local rule/protocol, MRI radiographers and consultant radiologists are on-call from home and any case of suspected CES is discussed with the consultant radiologist and if agreed, the MRI radiographer travels to the hospital to perform the scan. While this arrangement supports timely diagnosis, it also presents additional costs and challenges such as increased workload and fatigue.

Several studies have assessed the timings of diagnosis and treatment of CES [6–9,11,14]. but mainly at the referral or tertiary hospitals in the UK and elsewhere. Most acute hospitals in the UK do not have on-call services for CES but with increasing demand for 7-day NHS services, there is also the push for acute hospitals to provide round the clock MRI services for emergencies like CES. Given the perceived benefits of MRI on-call service weighed against some potential drawbacks, this study sought to determine whether the introduction of MRI on-call service at an acute hospital resulted in a significant improvement in the timely diagnosis of CES. The findings may help inform other acute trusts considering similar services, knowing that each trust has unique operational challenges and opportunities.

Methods

Ethical considerations

Ethical approval for the study was obtained from the relevant department at the NHS trust responsible for the study hospital; reference number FXP-56 and registered with the relevant ethics department in a UK University reference number ETH2122–0882. Though patients' data were used in the study, all identifiable details were either not collected or pseudonymised.

Design

The study was a retrospective clinical audit with quantitative analysis of the audit data comparing two timepoints: the pre-on-call timepoint was 12 months prior to the introduction of the on-call system (August 2020 to July 2021), and the post-on-call timepoint was 12 months after the introduction of the on-call system (August 2021 to July 2022). Retrospective design was deemed appropriate for this study because it was an audit, no intervention was applied and it involved measuring outcomes that have already occurred [21].

Data collection

All data were collected at the study setting, which is an acute hospital in the Southeast England providing emergency, planned and outpatient care. Data were obtained from the computerised radiology information system (CRIS). Clinical history and the examination requested were used as eligibility criteria to identify patients included in the study. For clinical history, keywords, and abbreviations "cauda equina," "Cauda equina syndrome," "CE" and "CES were used while "MRI Lumbar spine", "MRI Lumbar/Sacral spine" and "MLSPN" were used for the examination. All other requests for Lumbar spine without the clinical history relating to CES were excluded. All the scans were performed in a GE Optima 450 w 1.5T MRI scanner [22] with the following sequences-sagittal T2 weighted, sagittal T1 weighted and axial T2 weighted. The approximate scanning time for each scan was about 6 min. MRI examinations are performed in two stages: the first stage is acquisition of the MRI images (termed in this study the scanning stage) while the second involves production of MRI report (termed in this study the reporting stage). Timing of MRI examination began when request for query CES was received on CRIS and finished when the report of the scan was provided.

Population and sampling

The study population consists of all the patients that were referred for MRI scan for query CES in each of the two timepoints. This was made up of 160 patients for the pre on-call timepoint and 165 patients for the post on-call timepoint with a combined population of 325 patients. Considering this combined population of 325, sampling the entire population was deemed unnecessary therefore, the recommended formular to calculate sample size in clinical audit was adopted [23].

For 95% confidence level, +/−5% accuracy and binomial data,

Sample Size = 1.96^2 x N x p(1-p)/(0.05^2 x N) + (1.96^2 x p(1-p) where 1.96 is the constant for 95% confidence level, N is the population, 0.05 is the required range of accuracy (confidence interval) and p is the percentage of cases for which you estimate the measure of quality will be present (or absent).

The above formula was deemed appropriate because the study meets the main conditions for its use namely having binomial data (scan completed within 24 h-YES/NO) and assuming that 50% of the scan will be completed within 24 h. The assumption of 50% was chosen instead of the locally agreed 95% target because detection of a 50% timely scan completion rate with an adequately narrow 95% confidence interval of +/-5% will require a much higher sample size than the 95% target and thus a better representation of the study population. Higher sample sizes are preferred to lower ones because they provide better estimates, more confidence and smaller test errors thereby producing stronger statistical conclusions [24]. Using the above formular, 113 was calculated for the pre on-call timepoint and 116 for the post on-call timepoint; the difference was due to different population sizes. However, 116 sample size was used for each timepoint for easy comparability with combined sample size of 232.

Simple random sampling was used to select 116 patients in each timepoint. This was done in Microsoft Excel (version 2022) [25] that assigned random numbers to each of the patients and randomly rearranged them in no particular order with each patient having equal chance of being included in the sample.

Analysis

For easier analysis, Microsoft Excel (version 2022) [25] was also used to break the two timepoints into different requesting periods contained in Table 1.

Data were analysed using the statistical package for the social sciences (SPSS) version 27 [26]. Categorical variables were described in terms of their frequencies. Mean and standard deviation (SD) were used to describe normally distributed continuous data while median and interquartile range (IQR) were used to describe continuous variables that were skewed. Normality in data distribution was determined using skewness, kurtosis, and Shapiro-Wilk test. Most tests/descriptive statistics in this study were nonparametric because data on examination time were heavily skewed. The mean (a parametric statistic) can be distorted when data is very skewed, and it is generally recommended that the median (a non-parametric statistic) should be presented instead [27]. However, some reports of mean in this study denote average time. Chi square ($\chi 2$) tests were used to compare proportions of requests completed within the 24-h target. Mann-Whitney U tests were used to compare the difference in the examination time between the two timepoints and difference in the time taken to complete each stage of the MRI examination in the two timepoints. Comparisons of examination times between different request periods in the two timepoints were evaluated using the Kruskal Wallis test, followed by pairwise post-hoc tests. The pairwise tests applied Bonferroni correction for multiple tests and the adjusted p values were reported. Only pairwise comparisons involving corresponding

Table 1
Requesting periods.

Period	Explanation
In hours Pre	This refers to 7.30am to 7.30pm in the pre on-call timepoint when the MRI unit was in operation
In hours Post	This refers to 7.30am to 7.30pm in the post on-call timepoint when the MRI unit was in operation
On-call hours pre	This refers to 7.30pm to 10.00pm in the pre on-call timepoint when the MRI unit was closed and on-call service was not in place
On-call hours post	This refers to 7.30pm to 10.00pm in the post on-call timepoint when the MRI unit was closed but there was an on-call service
Out of hours pre	This refers to 10.00pm to 7.30am in the pre on-call timepoint when the MRI unit was closed
Out of hours post	This refers to 10.00pm to 7.30am in the post on-call timepoint when the MRI unit was also closed

Table 2
Distribution of patients based on demographic characteristics.

Variable	Category	Timepoints		Timepoints combined Frequency (%)
		Pre on-call Frequency (%)	Post on-call Frequency (%)	
Age (Years)	35 and below	31 (26.7)	33 (28.4)	64 (27.6)
	36 to 64	62 (53.4)	61 (52.6)	123 (53.0)
	65 and above	23 (19.8)	22 (19.0)	45 (19.4)
Gender	Male	38 (32.6)	43 (37.1)	81 (34.9)
	Female	78 (67.2)	73 (62.9)	151 (65.1)
Ethnicity	Asian	23 (19.8)	31 (26.7)	54 (23.3)
	Black	4 (3.4)	2 (1.7)	6 (2.6)
	Mixed	1 (0.9)	0 (0.0)	1 (0.4)
	White	81 (69.8)	72 (62.1)	153 (65.9)
	Others	3 (2.6)	4 (3.4)	7 (3.0)
	Unknown	4 (3.4)	7 (6.0)	11 (4.7)

periods between the pre on-call and post on-call timepoints were reported. All tests were two-tailed with statistical significance set at $p < 0.05$.

Results

Patients' demographic characteristics

There were similar distributions in age group, gender and age range across the two timepoints compared. Out of 116 patients in each timepoint, slightly more than half of them were in the middle age group (36 to 64 years), and nearly two third were females. The age range was 16 to 94 years in the pre- on-call period, with a mean (SD) age of 47.8 (17.4) years, and 19 to 95 years in the post–on-call period, with a mean (SD) age of 49.2 (17.8) years. Further details of patients' demographic distribution are displayed in Table 2.

Comparison of examination time between the two timepoints

The average time from request to scan (scanning stage) in this study was found to be almost twice that of the time from scan to report (reporting stage) and this was observed in both timepoints. The descriptive statistics of these two stages of MRI examination in the two timepoints were shown in Table 3.

The comparison of exam time between the two timepoints using Mann Whitney U test demonstrated no statistically significant difference in the exam time (time to complete the study) between the pre on-call and the post on-call timepoints ($p = 0.739$). Equally there was no statistically significant difference in the time taken to complete each stage of the MRI examination in the two timepoints as follows; request to scan time ($p = 0.442$) and scan to report time ($p = 0.087$).

Comparison of examination time based on when MRI requests were made

As shown in Table 4, the average time taken to complete requests received during the In Hours period for the pre on-call timepoint and that of the post on-call timepoints were almost the same at 5.0 h and 4.8 h, respectively. The same was true for the out of hours periods in the two timepoints. However, in the on-call hours, scans took more than three times as long to complete in the pre on-call timepoint compared to the post on-call one.

The Kruskal-Wallis test used to evaluate the statistical differences in the time taken to complete MRI examinations before and after the introduction of the on-call system with data grouped by the time requests were received revealed a statistically significant difference between the timepoints ($H = 74.5$, d. $f = 5$, $p < 0.001$). Post hoc tests for pairwise comparisons performed showed a statistically significant longer exam time when requests were received during the on-call hours of the pre on-call timepoint compared to that of the corresponding period in the post on-call timepoint (adjusted $p = 0.006$). There was no statistically significant difference between pre- and post-introduction of the on-call system in the time taken to complete the exam when requests were received in the in hours and out of hours periods (adjusted $p = 1.0$ for each).

Table 3
Stages of MRI examination across the timepoints.

MRI pathway and examination time	Pre on-call		Post on-call		Mann Whitney U test result	
	Average (Mean) (Hours)	Median (IQR) (Hours)	Average (Mean) (Hours)	Median (IQR) (Hours)	U	P Value
Request to scan time	5.2	1.9 (0.7–7.6)	4.6	2.4 (0.9–6.7)	6335.0	0.442
Scan to report time	2.2	1.5 (0.9–2.3)	2.1	1.4 (0.8–2.0)	5854.5	0.087
Time to complete study	7.4	3.7 (2.1–10.6)	6.7	4.1 ((2.1–9.2)	6558.0	0.739

Table 4
Descriptive statistics based on when MRI requests were made.

Request periods	Examination time		Total requests
	Average (Mean) (Hours)	Median (IQR) (Hours)	Frequency (%)
In hours Pre	5.0	2.7 (1.9–4.4)	84 (36.2)
In hours post	4.8	3.5 (1.9–4.8)	78 (33.6)
On-call hours pre	20.5	17.4 (15.6–18.6)	7 (3.0)
On-call hours post	6.1	2.2 (1.8–13.6)	12 (5.2)
Out of hours pre	11.7	9.6 (7.7–14.1)	25 (10.8)
Out of hours post	12.7	10.9 (7.6–12.1)	26 (11.2)

Table 5
Distribution of MRI requests completed within the target time frame.

Periods requests were received	Completed within 24 h	
	Yes Frequency (%)	No Frequency (%)
In hours pre	83 (98.8)	1 (1.2)
In hours post	77 (98.7)	1 (1.3)
On-call hours pre	6 (85.7)	1 (14.3)
On-call hours post	12 (100)	0 (0)
Out of hours pre	23 (92.0)	2 (8.0)
Out of hours post	25 (96.2)	1 (3.8)

Association between request periods and completion of MRI requests within 24 h

The numbers of MRI requests completed within 24 h in the in hours periods of both timepoints were above the target of 95%. However, for requests made during the on-call hours and out of hours periods, completion of ≥95% of requests within 24 h was only achieved during the post on-call timepoint. Further details are shown in Table 5.

A chi square ($\chi 2$) test was performed to evaluate any association between the request periods in the two timepoints with completion of MRI exams within 24 h. The result indicated that completion of MRI exam within 24 h was not associated with the periods requests were received in both timepoints ($\chi 2$ (5) =8.4, $p = 0.137$).

Discussion

Main findings

This study found that the average time to complete scans was reduced by 0.7 h (about 9.5%) in the post on-call timepoint. However, when the timepoints were broken into different periods based on when the requests were made, the examination time was reduced by 14.2 h (about 70.2%) in the on-call hours of the post on-call timepoint compared to the corresponding period in the pre on-call timepoint.

The locally agreed target of scanning 95% of requests for CES within 24 h was achieved in all the different periods in the post on-call timepoint while the target was only achieved during the in hours period of the pre on-call timepoint. However, there is no statistically significant difference in achieving the stipulated target across both timepoints.

Interpretation of findings and comparisons with other studies

In this study, the median time from when the requests were received to when the scans were completed was 3.7 h for the pre on-call timepoint and 4.1 h for the post on-call timepoint. Foutain et al. [6] reported that the median time between patients' presentation and undergoing MRI examinations for suspected CES was 2.84 h if requests were made within the spinal unit of a tertiary hospital. For requests made outside the spinal unit (another specialty) within the same tertiary hospital, the median time was 3.12 h and for patients transferred from another hospital, the median time from presentation to undergoing MRI examination was 13.9 h. The MRI services for patients with suspected CES at the study hospital seemed quicker compared to similar acute hospitals where transfers to tertiary hospitals were required for scans. Though figures in this study were lower than obtained in a tertiary or referral hospital, they are comparable giving that such hospitals have 24 h MRI cover for suspected CES. This implies that patients with suspected CES will likely have their scans in a timely manner comparable to a referral centre. This will in turn facilitate early intervention if required. This was made possible by well organised workflow with prioritisation of scans for CES. Besides, the 7-day MRI service with 12 h each day also contributed in reducing the window period patients have to wait for scans.

In this study, the on-call service led to only a 9.5% overall reduction in examination time, which was much lower than the 29.0% and 36.0% reductions reported in two PDSA cycles by Buell et al. [11] However, during the on-call hours, examination time decreased by 70.0% for requests received during the post on-call timepoint. This was because requests made during on-call hours were immediately scanned under the on-call arrangement sometimes completed within an hour while similar requests in the pre on-call timepoint were either referred out or delayed until the MRI unit reopened at 7:30am. Despite the large improvement during on-call hours, the overall impact was limited due to the short on-call window (only 2.5 h, from 7:30 pm. to 10:00 pm.) and the small number of requests (only 12) received during the period. This low requests likely reflects strict referral guidelines and required consultant-to-consultant discussions, ensuring only appropriate requests were accepted. Besides, the study by Buell et al. [11] was conducted at a referral center with 24-h MRI on-call services, more resources, and specialist staffing; factors that may have contributed to their greater improvements. Nevertheless the 9.5% (0.7 h) reduction in examination time during the post on-call timepoint may not be statistically significant but in emergencies like CES, any gain in time may have significant clinical outcome.

While it was interesting to note that the introduction of the on-call service did not translate to a statistically significant reduction in MRI examination time partly due reasons given above, it was surprising that the study demonstrated that completion of MRI examinations within 24 h was not associated with when the requests were received. The expectation was that requests received outside the normal hours will be more likely to be completed in >24 h compared to those received during normal hours. However, the oraganised vetting and prioritisation system of workflow in place even before the introduction of the on-call enabled requests to be completed in good time. The on-call was an additional measure to further improve the timely imaging of CES. Even when the requests are made out of hours there are high chances that the scans will be completed within 24 h since the MRI unit operates 12 h per day, 7 days per week.

Study implications and recommendations

The findings of this study suggest that introduction of an on-call system can be an efficient way to reduce time to diagnose patients with CES for referrals received during the on-call period, and imply that an overall reduction in the time taken to diagnose CES could potentially be achieved with further extension of the on-call period beyond the current 10pm cut off. Reduction in the time taken to diagnose CES means that patients' management can change in the sense that timely interventions are offered if positive diagnoses are obtained in line with what was reported in literature [20,28,29]. However, any further extension will be limited by staff availability and cost implications. Hauptfleisch et al. [30] suggested using some CT radiographers who already perform night and weekend shifts as part of their normal rostering. Training and using such staff could be a cost effective solution for conducting overnight MRI scans for patients with suspected CES. This arrangement seems feasible at the study hospital where a good number of such CT radiographers are trained and rotate through MRI. Based on the findings of this study and above discussions, follow up audits of the On-call service will help monitor progress. Further studies on the causes and impacts of delays in diagnosis of CES as well as comparative study with a similar hospital setting to assess best practice are recommended.

Study limitations

A key limitation of this study is that the on-call period examined was only for 2.5 h, during which a small number of requests were received. As a result, any potential time-saving benefits within this short window are unlikely to have a significant impact on overall examination times. The study also used retrospective data and as such no control on the quality and type of data to be collected. This will make it difficult to account for cofounding factors. For instance, some scans were not completed as expected due to some inherent problems in MRI like claustrophobia and MRI conditional implants that needs certifying for safe scanning. Additionally, as this was a single-center study, the findings may not be generalisable beyond the study hospital.

Conclusion

CES requires urgent intervention in order to prevent irreversible neurological damage. MRI examination is currently the choice diagnostic tool for CES, and it should be carried out on patients with suspected CES within the shortest possible time to facilitate urgent surgical intervention. At the study hospital, a 2.5 h on-call service was introduced to help reduce the length of time taken to diagnose patients suspected of CES. This study demonstrated that on-call service can reduce the time it takes to diagnose patients with suspected CES but the length of the on-call hours was not sufficient to bring about statistically significant reduction in the overall examination time. However, the reduction may have clinically significant outcome in emergency scenario like CES. Extension of the on-call service beyond the current 2.5 h may be considered with the expectation that it may further reduce MRI examination time thereby ensuring timely diagnostic imaging of suspected CES.

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