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Change in urban and non-urban pattern of ED use during the COVID-19 pandemic in 28 Michigan hospitals: an observational study

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ABSTRACT

Objective To assess the trends in visits, overall and by age, to urban and non-urban emergency departments (EDs), and visits resulting in admission to hospital before and during the COVID-19 pandemic using a large regional database.

Setting A large regional database of 28 EDs during the COVID-19 pandemic in Michigan, with an index case of 11 March 2020 and peak in the first week of April.

Participants ED visits during the first 5 months of the calendar year were included and compared with the previous year. Facilities where these participants were seen were classified as urban or non-urban, with comparisons of total visits, COVID-like cases, paediatric and trauma.

Outcome measures Daily visits to EDs of patients presenting with COVID-like symptoms, trauma, age patterns and total cases, and stratified between urban and non-urban settings.

Results There were 1 732 852 visits across the 2 years, 953 407 between study and comparison periods, and 457 130 visits defined as COVID-like (median age 44 years). Total ED visits decreased to 48% of the previous year, showing a delayed-inverse relationship with COVID-19. Trauma cases dropped but returned to the pre-COVID-19 rate by the end of May in Urban centres. Paediatric cases decreased to 20% of the previous year by the end of April. The oldest age groups showed the least change in ED visits in response to the pandemic.

Conclusions This large US Midwestern state study describes a dramatic decrease in ED visits after the onset of the COVID-19 pandemic in Michigan, including stratification by varying ages and trauma, demonstrating the tangible impact of the COVID-19 pandemic on urban and non-urban EDs.

Strengths and imitations of this study

- This was a large study, in two comparison groups from 2019 and 2020 which may contribute to external validity of the results.
- A comparison between urban and non-urban accident and emergency departments was conducted using Rural Urban Continuum Codes, allowing differentiation between these two, sometimes disparate healthcare settings.
- The COVID-like case definition for this study was created using influenza-like chief reports and billing codes that resulted in an overall decrease in COVID-like cases when comparing the pandemic period with the previous year, but nevertheless allowed for comparison between subgroups.
- Race and ethnicity are not available in the administrative data used for this study.

INTRODUCTION

The index case of COVID-19, caused by SARS-CoV-2, in the USA was reported on 31 January 2020, and the first case in the state of Michigan on 11 March in the same year.[1 2] The peak test positive cases reported to the state for COVID-19 occurred across the month of April, with the highest number reported on the first week of the month. This immediately followed the usual seasonal influenza peak for that year.

Emergency departments (EDs) and hospital inpatient wards in affected regions were impacted greatly by the increase in arrivals of patients with suspected or confirmed SARS-CoV-2 infection and use of personal protective equipment (PPE) was widely instituted. In many regions of the world, ED use has been reported to become majority COVID-19 related, as other potential patients choose to avoid the ED during the pandemic, with a decrease in overall ED visits and increase in hospitalisations. Previous studies have shown how lockdown measures led to a significant decrease in ED visits and increase in hospitalisations.[3–9] This has been described in the media as well.[10 11]

A recent study published by the Centers for Disease Control and Prevention described COVID-19 in EDs, noting the decreased volume in EDs and age distribution, but reported results of urban and non-urban cases together.[12] Urban and non-urban cases can be expected to vary, and combining them

together may result in underestimating impacts of the pandemic for the ED setting. In addition, it is beneficial to describe COVID-19 impact based on an individual large region rather than the entire nation, because this most accurately replicates the pattern of spread of the virus.

Analysis of the current experience has the potential to provide critical 'lessons learnt' for geographical regions still only mildly or moderately affected by this pandemic, and for similar events in the future. The objective of this study is to describe urban and non-urban ED visits during the COVID-19 pandemic, referencing both the time shortly before the outbreak and corresponding months the previous year. In addition to stratifying by age, type of facility (urban vs non-urban) and admissions, we also aimed to describe the change in frequency in ED diagnoses codes during the same period and in the level of acuity of presentations.

METHODS

Source of data

This retrospective cohort study used visit-level administrative data from Data to Intelligence, a healthcare data analytics application that aggregates data from electronic health records from across the USA. The data include ED census and location, patient age, sex, report, diagnosis codes and disposition. Because this database is used for billing, race and ethnicity are not recorded. These data are an essentially complete capture of all ED visits from the defined time periods. Due to the large size of the data, no sample size calculation was performed.

Study design, population and setting

This study used a subset of 28 EDs in the state of Michigan, encompassing urban and non-urban locations. Data were abstracted for ED visits from 1 January 2020 to 31 May 2020 (exposed group), covering the peak months of COVID-19 pandemic in the USA, and comparable data from the same interval in 2019, from January to May (comparator group). Groups were defined using a combination of ICD-10 codes and selected chief reports. The groups studied over the defined time period included the following: (1) total, (2) COVID-like, (3) paediatric, (4) trauma. The primary outcome measure is to describe daily visits to EDs of patients presenting with COVID-like symptoms in urban and non-urban settings. Secondary outcome measures are describing changes in trauma cases, age patterns and total cases, and stratified between urban and non-urban settings.

The COVID-like case definition for this study was created using chief reports and billing codes that were selected using an American College of Emergency Physician COVID-19 diagnostic criteria list,[13] plus the addition of ICD-10 codes for influenza-like illness. Although this method is necessarily inexact, we believe it reflects the cases of concern that would require use of PPE and heightened safety measures by healthcare workers. To partially enhance this definition, cases where the clinician suspected COVID-19 enough to request testing were also considered COVID-like. Trauma cases were defined using the National (US) Trauma Center criteria.[14] Furthermore, the state of Michigan received no more positive influenza tests after 12 March 2020. This closely paralleled influenza testing throughout the USA, suggesting that influenza-like symptoms after this date were considered much more likely related to COVID-19. Thus, because a diagnosis of COVID-19 or influenza could not be differentiated at the time, the terms 'COVID-like' and 'influenza-like' when referring to the type of ED visit are synonymous.

Data analysis

The number of ED visits of each type (trauma, paediatric, COVID-like, total) were aggregated by facility/patient sex/day (possibly stratified by factors including urbanicity and patient age band) and were then analysed descriptively using graphs of smoothed data, and formally using Poisson regression. Key findings are based on Poisson regression analysis fit to each visit type/facility/sex/day using the number of visits on each single day in 2020 as the outcome variable and the logarithm of the number of visits in a 7-hour period centred on the same day of 2019 as an offset.[15] To quantify the change in visits between 2019 and 2020, the expected number of visits per day in 2020 was modelled as a 10° of freedom B-spline function of the week-long smoothed ED visit counts from 2019. The predicted values from Poisson regression with an offset are estimates of the incidence ratio between the control (2019) and exposure (2020) periods, estimated on a daily basis for multiple relevant subpopulations. SEs and other uncertainty assessments use time-series adjustments, based on cluster-robust SEs calculated using the autocorrelation of the residuals. The spline degree of freedom was assessed by information criteria (quasi-Akaike's Information Criterion) and sensitivity analyses using a range of choices for this value. Results for facility/sex were aggregated, weighted by sample size, to produce person-weighted results for either all facilities, or all facilities in a Rural Urban Continuum Code class. Urban facilities were defined as those having equal to 1 or 2 and non-urban EDs as 3–9.[16]

Changes in utilisation of primary diagnosis codes were performed by comparing the proportion of cases having each diagnosis code in April 2019–April 2020, using the standard two-sample statistical test for proportions. Z-scores reflecting statistical significance and rate ratios reflecting effect size were assessed using local false discovery rate methodology to identify codes with potentially meaningful changes.

Data analysis was conducted using scripts written in Python (Travis E. Oliphant. Python for Scientific Computing, Computing in Science & Engineering, 9, 10–20, (2007)) and Go (available at github.com/kshedden/micovid). Patients presenting with symptoms similar to or indicative of COVID-19 were grouped together using a non-exhaustive list of chief reports and

Table 1 Characteristics of patient visits and emergency departments (EDs)

Demographic information	January 2019–May 2019		January 2020–May 2020	
Sex	ED visits	% of total	ED visits	% of total
Female	292 093	55.4	229 028	53.7
Male	234 976	44.6	197 310	46.3
Geographical location				
Non-urban	128 463	24.4	106 299	24.9
Urban	398 606	75.6	320 039	75.1
Age				
0–18	81 132	15.4	58 285	13.7
19–30	99 151	18.8	76 617	18.0
31–50	131 319	24.9	110 428	25.9
51–70	128 527	24.4	109 280	25.6
71+	86 940	16.5	71 728	16.8
Median age	42.2		43.6	
Disposition				
Non-influenza-like	387 809	73.6	291 634	68.4
Influenza-like	139 260	26.4	134 704	31.6
Admissions				
Admitted	78 252	14.8	74 785	17.5
Not admitted	448 817	85.2	351 553	82.5

Administrative data from 28 EDs in Michigan.

ICD-10 CM codes. Trauma cases were grouped together according to the National Trauma Data Standard Patient Inclusion Criteria.[14] Emergency Severity Index (ESI) was used to evaluate change in acuity of disease by those seeking consultation in the ED. Admissions were reported as urban or non-urban and reported graphically. Missing data were left unadjusted.

Patient and public involvement

This study evaluated patient's use of the accident and emergency departments in Michigan. It was anticipated that this would provide insight into the effect of COVID-19 on the patient's decision to use or defer healthcare during the pandemic. There were no patients or patient advisors directly involved in the design or execution of this retrospective study. The results of this study will be published in an open-access format, allowing greater ease of the public and media outlets to view and evaluate the findings.

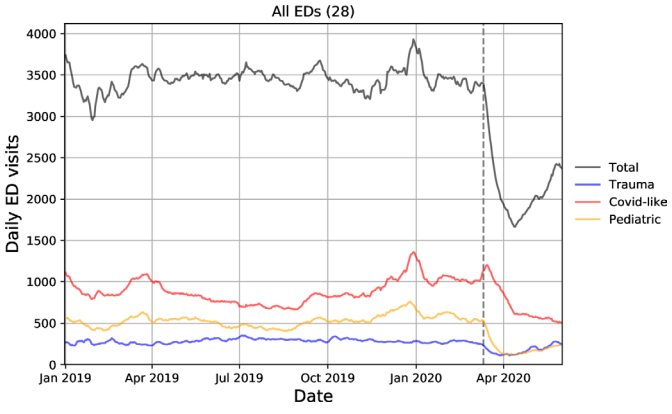

Figure 1 Emergency department (ED) use during the COVID-19 pandemic in Michigan. Author's analysis of administrative data from 28 EDs in Michigan. ED use: total, trauma, COVID-like and paediatric. Aggregated data include 28 EDs across the region.

RESULTS

Characteristics of the two comparative years are presented in table 1. The same selection criteria and data provider were consistent across the 2 years.

Overall changes in ED usage during peak of COVID-19 pandemic

The median facility had a reduction in total patients to 47% (range 27%–85%) of the previous year's volume. The nadir in the aggregated data occurred on 15 April (figure 1). By 31 May, the median facility had returned to 70% (range 49%–92%) of its pre-COVID-19 volume. The total paediatric visit volume fell further than total volume, with the median facility having 22% (range 9%–33%) paediatric volume relative to the previous year.

Changes in urban and non-urban ED usage

In both urban and non-urban EDs, the total number of daily ED visits dropped in April 2020 compared with the corresponding month in 2019 reaching a nadir in April

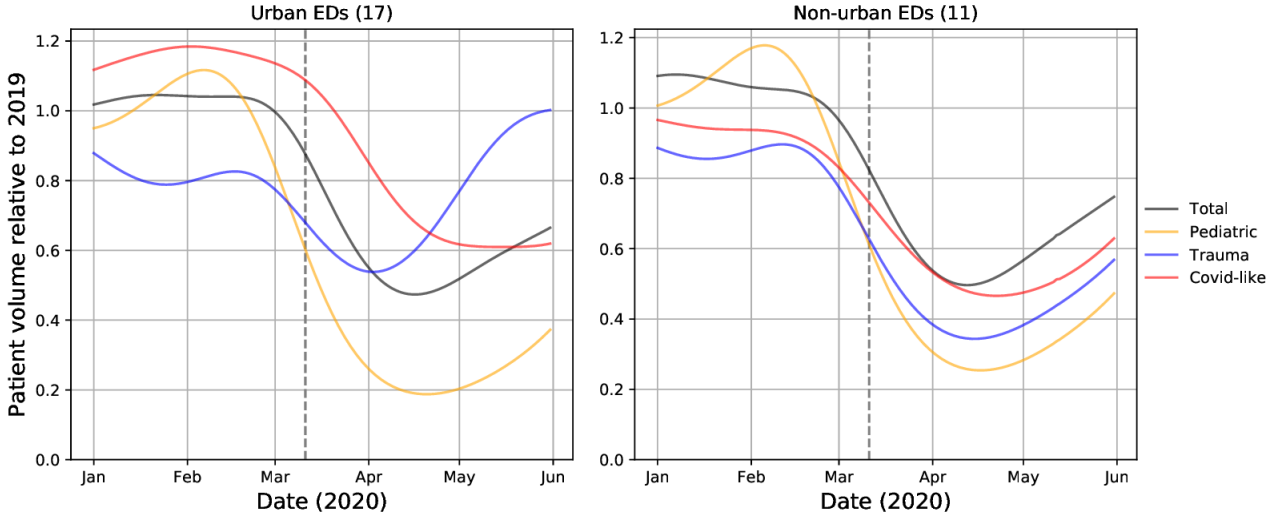

Figure 2 Ratio of visits by category comparing 2020 with 2019. Aggregated data of 28 emergency departments (EDs) in Michigan. The defining criterion for COVID-19 includes influenza-like symptoms. Comparison with previous year results in ratios of <1 during parts of the current pandemic. The dashed lines indicate the index COVID-19-test positive case in Michigan.

to 48% (45%–50%) as compared with the same period in 2019, and the total number of cases continued to be lower than 2019 through the end of May (figure 2).

Trauma cases decreased immediately after the COVID-19 index case, reaching a nadir of 54% (urban) and 34% (non-urban) relative to pre-COVID-19 levels. However, trauma rebounded rapidly in urban facilities, returning to pre-COVID-19 levels by 31st May, whereas trauma cases in non-urban facilities were at 57% of pre-COVID-19 levels on the same date.

Both urban and non-urban centres showed a sharp decrease in the daily number of paediatric cases starting in February 2020, decreasing to nearly 20% relative to 2019 by May 2020. Total volumes dropped slightly more for non-urban hospitals (47% non-urban vs 50% urban). The overall admission rate (including both adult and paediatric) relative to 2019 sharply increased for both urban and non-urban EDs, with peak in mid-April (online supplemental figure 1). Admissions in urban centres were lower in 2020 relative to 2019 in urban centres until March, when there was a marked increase to a peak in mid-April, with increase to 147% (95% CI=134% to 161%) for urban and 141% (95% CI=120% to 167%) for non-urban EDs (online supplemental figure 1).

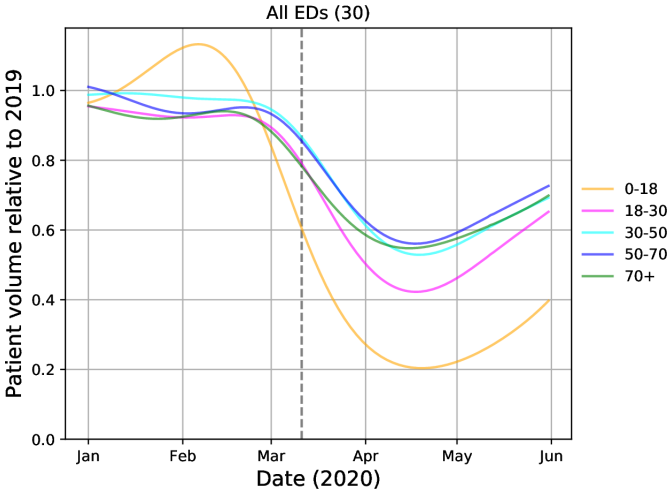

Figure 3 Use of the emergency department (ED) by age group. Author's analysis of administrative data from 28 EDs in Michigan. Plot of ratio of visits January–June 2020 vs 2019. Vertical dashed line corresponds to index COVID-19-test positive case in Michigan, March 11.

Changes in ED usage by age and ESI and diagnosis

Evaluating for age, paediatric use of the ED (age <18 years) dropped to 20% (95% CI=18% to 23%) of pre-COVID-19 levels, while the geriatric group (age >70 years) dropped only to 55% (95% CI=52% to 58%) (figure 3). The paediatric visit volume ratio showed the greatest decline across all age groups. A review of changes in ED visit diagnoses after the index case of COVID-19 in Michigan revealed that there were large increases in patients presenting with alcohol intoxication (23-fold), anxiety (1.7-fold) and a decrease in patients seeking chronic pain relief as a chief report (online supplemental table 1). ESI changes were noted to shift towards higher acuity, corresponding to lower ESI numbers (1=life-threatening, 5=lowest acuity, requires no resources),[17] with 2020 having more severe ESI levels than 2019 (p<0.001). Specifically, in 2020 there was a 1.2% increase in ESI 1 (95% CI=0.12% to 2.3%), 6.4% increase in ESI 2 (95% CI=5.4% to 7.3%), 3.1% decrease in ESI 3 (95% CI=−0.039% to −0.024%) and 4.7% decrease in ESI 4 (CI=−5.7% to −0.03.8%). There was no significant change in level 5 between the 2 years, which also had the lowest number of visits (fewer than 2500 visits in each year).

DISCUSSION

Overall, our study shows that total ED visits decreased by 48% after the first index case of COVID-19 in Michigan when compared with the same time period in 2019. The

number of trauma and paediatric ED visits, as well as overall hospital admissions, also decreased. When stratifying by age, the oldest age groups experienced the least change in the number of ED visits. Frequencies of certain chief reports also changed significantly, such as anxiety, alcohol intoxication and patients seeking pain relief.

Coronavirus has a global reach. However, in the USA and other parts of the world, the pandemic does not impact vast national or continental geographies simultaneously. Instead, different specific regions tend to be involved at a given time. This is understandable, given population density is known a major environmental determinant of viral spread.[18] To our knowledge, this is the first description of a large regional database which compares urban and non-urban ED visits during the early and peak COVID-19 pandemic in a specific region of the USA. Urban centres exhibited an increase in COVID-like (influenza-like) cases from January 2020 through the middle of April 2020 when the number of cases began to drop sharply in most facilities. In contrast, non-urban centres had fewer influenza-like cases compared with 2019. The volume of patients with influenza-like symptoms relative to 2019 decreased dramatically starting slightly before the index COVID-19 case in Michigan, reaching a minimum in April 2020. It was also noted that the total ED volumes dropped slightly more for non-urban hospitals (47% non-urban vs 50% urban). This may be explained by the impact of urban density on spread of the virus. These findings may be the result of greater population density near the urban centres being associated with more infected individuals.

As was seen in other studies, there was a marked drop in patients seeking care in the ED. This may be due to public concern of being exposed to the virus in the waiting rooms or ED proper.[19] This has sparked concern that cases needing time-sensitive care may be avoiding the ED with the potential of worsening health outcomes in these individuals.[20] It is not clear what proportion of these patients shifted to office or urgent care visits. Telehealth has also become increasingly available but was not likely to be a significant factor early in the pandemic. It is also noted that there was a sharp V-shape of the total case-curve, as patients started to return to the ED in greater numbers. However, this return of the public to the ED seems delayed until after the nadir of COVID-like cases and with a less steep slope than was seen early in the pandemic. This implies a latency in public confidence regarding the safety of the ED environment. Administrators are implementing physical changes in departmental layout and public information campaigns to encourage return of appropriate patients.[19] In addition, shortly after the first index case of COVID-19 in Michigan, a stay-at-home order was enacted which also required for non-essential businesses to close in-person operations.[21] This may have also limited the willingness of the public to visit EDs.

The perception among many who worked across the region was that the proportion of coronavirus cases seemed much higher in urban settings than in non-urban environments, and this was confirmed by the data (figure 2). It is likely that this is the result of urban population density increasing the rate and intensity of COVID-19 cases. It is noted that there is a delayed-inverse relationship of total cases following the COVID-like peak.

There was an above average and late influenza season in Michigan the prior year,[22] whereas influenza testing went to near zero in the 14th week of 2020, which corresponds very closely with the index case of COVID-19 positive testing in Michigan. This study made use of influenza-like illness as a proxy for COVID-like illness, and many facilities had similar or lower levels of this type of visit during the COVID-19 period compared with 1 year prior. Aggregate COVID-like visit volume follows the overall visit volume, dropping during the peak period of COVID-19 activity. It is noted that there is a greater drop in COVID-like cases in non-urban centres, which may be due in part to referral of persons under investigation with COVID-19 being referred to these larger centres. However, total cases dropped substantially in both urban and non-urban EDs. It is interesting to note that trauma initially dropped but returned to baseline by 30th May in the urban facilities.

The data reveal the greatest decrease in use of the ED, or elasticity of demand, occurred in the paediatric population, which dropped to a visit volume of only 20% of the previous year. The smallest drop occurred in the >50 age population, 51% change of the previous year. This relatively inelastic demand may be explained by the higher acuity of care and more limited options for the geriatric population. The decrease in ED use for paediatric patients may reflect concern for both child and parental exposure to the virus. It is noted that the facility with the greatest drop in patient volume was a large, inner-city children's hospital ED, which saw a decrease to only 30% of its pre-COVID-19 volume during the peak of the pandemic. In the geriatric population, the more inelastic demand may reflect higher acuity of illness, less autonomy and less ability to defer healthcare. ESI changes were noted to shift towards higher acuity (corresponding to lower numbers), with 2019 having higher ESI levels than 2020 ($p<0.001$).

The percent of visits that resulted in admission increased for both urban and non-urban EDs during the pandemic, with the peak occurring in mid-April, 2020, about 1 week following the peak of testing positivity in the state, which occurred in the first week of April (Michigan Daily Coronavirus Data 2020). Although the percent of admissions increased, the absolute number decreased during the 2020 pandemic.

The authors evaluated changes in diagnostic categories and acuity levels of patients seen in the ED with the largest changes (increase or decrease), reported as ratios to total patients for the peak month of the pandemic (April), as compared with the same month in the previous year (online supplemental table 1). It is noted that patients seeking relief from chronic pain decreased appreciably during the pandemic. This may reflect greater ED usage/

demand elasticity of this group, or simply a shift to clinic settings and later, telemedicine. Otitis media also decreased, which is consistent with the decrease seen in paediatric visits to the ED. It is interesting to note that there was also an increase in alcohol use disorders and anxiety disorders during the pandemic. These are findings that suggest a need for deeper analysis and future research. The decrease in trauma visits during the pandemic may provide insight into opportunities for injury prevention. The data presented graphically in this study used National Trauma Center criteria, showing a decrease after the stay-at-home order enacted on 24 March.[21] Interestingly, this was not noted in the top 15 decreased diagnoses, perhaps because this fell below the 15-diagnosis threshold used in this part of the study. The decrease in visits due to chronic pain-related reports may point to an opportunity to refer some of these patients to non-emergent care or telemedicine. The code for unspecified pain includes acute pain, and this increased during the pandemic.[13]

Limitations

Early in the pandemic COVID-19 testing was very limited at all sites in Michigan.[23] This was an important challenge in the initial response to the outbreak with respect to availability of testing for SARS-CoV-2, making it difficult for providers, policymakers, and the general public to better understand, prepare and respond to the volume of patients with confirmed COVID-19.

Race and ethnicity are not available from the administrative database used here. Hence, we were not able to provide ED usage based on these parameters. However, urbanicity might provide a rough estimate of these racial and ethnic differences.

This was an observational study that describes the experience of a large, diverse midwestern state that may differ from other regions of the USA. The number of visits included in the study was large, including 1.7 million visits taken from 28 hospitals in a state-wide cohort, including a variety of urban and non-urban hospitals which may add to the generalisability of the results. The specific geographical locations of the included hospitals, however, are unable to be specified due to confidentiality, so any nuance in the progression of the pandemic in these areas cannot be described. Furthermore, 2020 was compared only with 2019, so the study design does not account for underlying trends in ED attendance over the previous years.

CONCLUSION

In this study of 28 EDs during the 2020 COVID-19 pandemic in Michigan, there was a dramatic drop in total ED and paediatric visits in both urban and non-urban facilities corresponding with the influx of COVID-like visits, with higher visits in urban environments compared with non-urban environments. Higher trauma visits and peak overall admissions were also seen in urban environments. The admission rate increased during the peak of the pandemic in both urban and non-urban EDs. Patient volumes overall trended towards baseline shortly after the nadir of coronavirus-like cases.

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Contributors DK and BH conceived the project. BS provided data acquisition. DK, BH and KS designed and executed the protocol. KS conducted statistical analysis. All authors reviewed and edited the final manuscript.

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Patient consent for publication Not required.

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Provenance and peer review Not commissioned; externally peer reviewed.

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