Introduction

Emergency centre (EC) crowding has been described as both a patient safety issue and a worldwide public health problem [1]. The American College of Emergency Physicians defines crowding as when the identified need for emergency services exceeds available resources for patient care in the EC, hospital or both [2]. EC crowding has been associated with several adverse outcomes including increased morbidity and mortality, increased length of stay, increased costs, and decreased staff and patient satisfaction [2,3]. Low- to middle-income countries (LMICs) are not exempt: a study conducted in Khayelitsha Hospital, a district level hospital in the Western Cape of South Africa, found bed occupancy in the EC to be between 128% and 132%, depending on the time of day [4]. EC crowding in LMICs is further compounded by resource limitation, increased burden of disease and staffing shortages - 80% of LMICs have fewer than 10 medical doctors per 10 000 population with South Africa having 9.1/10 000 medical doctors per population compared with 25.95/10 000 in the United States of America [5,6].

Appropriate and efficient staffing is a cornerstone of EC performance. Strategic drivers regarding staffing includes quality of care, level of service and patient safety, while tactical drivers include patient volume and acuity, length of stay and clinician output [7]. EC clinician output has traditionally been described as patients consulted per hour (PPH) or in more recent years in some high-income countries as relative value units per hour (RVU/h), a resource based all-encompassing measure used to assist with billing for a clinician’s services. The RVU was developed to estimate a clinician’s work per patient based on patient acuity and diagnosis, practice costs and malpractice expense for a given intervention or service [8,9]. Several shift, clinician and workload factors affect clinician output and an understanding of these variables and the interaction between them will allow for a better balance between under- and
over-staffing, an optimal patient-to-clinician ratio and provide critical information to inform staff rosters and surge planning [8].

There is however a paucity of literature describing EC clinician output in LMICs and current staffing models are based on anecdotal evidence. The fiscal climate and resource restriction in LMICs further necessitate the need for cost effective staffing models that is based on local evidence. This study aimed to describe clinician output in a district level hospital in the Western Cape in South Africa and how it is affected by different shift, clinician, and workload factors.

Methods

This was a retrospective cross-sectional study of clinician shifts and patients seen, over three randomly selected four-week periods, using an existing electronic patient registry, to determine the PPH during each clinician shift and how it is affected by various clinician, shift, and workload factors.

The study was conducted at Mitchell’s Plain Hospital (MPH), a district level hospital in the Western Cape of South Africa. MPH serves a low-to-middle-income population of approximately 650 000 which includes Mitchell’s Plain, a 45km² suburb approximately 32km from Cape Town’s city centre, and the greater part of Philippi, a large nearby township. The case mix that presents to the 24-hour EC reflects South Africa’s quadruple burden of disease: maternal and child health, HIV/AIDS and tuberculosis, non-communicable disease, and violence and trauma [10].

The EC is managed by four consultant emergency physicians, who also manage a second emergency centre about 13 kilometres away. The staffing model utilises a four-week rotating roster which is staffed by four teams of four clinicians each. The core team comprises of an emergency medicine registrar (specialist in training), a medical officer (independently registered clinicians), and two community service medical officers (mandatory one year public service post internship). Teams are often supplemented with interns (newly qualified clinicians), extra MPH clinicians and locum medical officers. Clinician consultations are independent but senior staff, (registrars, medical officers, and consultants), are available to assist junior staff, (community service medical officers and interns), with clinical queries and patient care. The roster during the week is divided into three shifts with varying lengths and two 12-hour shifts during weekends.

MPH attends to on average of 50 000 patients annually and does not have an intensive care- or high care unit. Patients requiring these services, and those requiring after hour CT scans are transported to a tertiary facility about 30km away with subsequent long EC length of stays. There is a 24-hour onsite laboratory and radiological services but no onsite blood bank.

This was a descriptive study, and no sample size calculation was performed. A convenience sampling strategy was used which included each shift from three randomly selected non-contiguous four-week periods in 2019. Shifts for all clinicians working in the EC during the study period were eligible for inclusion. Patients who left before consultation were excluded.

Deidentified data were exported from the Hospital and Emergency Centre Tracking Information System (HECTIS) registry. The variables collected included the process times of all patients (from time of arrival until the disposition decision is made), the clinician category and the triage category according to the South African Triage Scale. The duty roster allowed for shift duration and category as well as the number of cumulative shifts worked to be collated. Cumulative shifts were defined as shifts beginning on consecutive calendar days. The disposition time was calculated as the time from consultation to disposition. Output was measured as patient per hour (PPH) and calculated as the total number of patients consulted by a clinician divided by the shift duration in hours. PPH calculated was simply a measure of patients consulted per hour. This measure does not take into consideration clinician workload, critical procedures or the use of diagnostic tools. Variance within a shift was calculated by dividing the shifts into quarters and calculating the average PPH for each quarter. The average number of boarders in the EC and the total number of patients in the EC during a shift was calculated by averaging two-hourly measures for each shift.

The data set was analysed using IBM SPSS Statistics version 27 and STATA 16. Categorical data were described with summary statistics and proportions. Continuous data that were not normally distributed and displayed as medians with interquartile ranges (IQR). Associations between PPH and shift factors were assessed using ANOVA with post-hoc adjustments such as the Bonferroni test where appropriate. PPH was not normally distributed and was transformed (squared) to perform robust parametric tests for inference. Statistical significance was defined as a p-value of <0.05. The correlation between PPH and workload metrics was calculated with the Pearson’s Rank correlation test. Workload metrics were further categorised into quartiles to allow for the data to be graphically depicted. The data was further analysed for any clinician clustering effect using a multilevel mixed-effects linear regression.

Ethical approval was attained from the University of Stellenbosch’s Health Research Ethics Committee (HREC S20/01/021) and facility approval achieved through the National Health Research Database website (WC_202006_041). All exported data was further deidentified for patient and clinician prior further analysis.

Results

Of the 1 291 clinician shifts that were eligible for inclusion during the study period of three months, two (0.15%) were excluded due to incomplete information. A total of 1 289 clinician shifts were included in the final analyses. A total of 11 841 patients entered the EC of which 9 668 patients were consulted by 111 clinicians; 1039 (9%) left before consultation, 118 (1%) were dead on arrival or demise in the EC, 6339 (53%) were discharged or deferred and 4345 (37%) were referred or transferred for higher care. Clinician clustering effect was assessed and found not to be present.

Table 1 summarises the characteristics of the shifts that were included for analyses with 55% of the shifts from senior clinicians (registrars and medical officers). The core EC team of four clinicians comprised 68% of all clinician shifts, while the rest consisted out of additional EC staff, locums, or clinicians from other departments. A total of 31% of all shifts were during office hours (08:00-17:00 on weekdays).

Table 2 summarises the triage acuity according to the South African Triage Sore for each patient per clinician category, as well as the respective disposition times (consultation-to-decision time). Most of the patients (51%) had a high acuity triage score (red and orange). There was an overall increase in the disposition times with increasing level of acuity as per the South African Triage Score. Registrars had the highest proportion of red consultations (7%) but had the longest overall average disposition time (3h25). Proportionally to the number of shifts, medical officers had the highest output with 44% of all consultations while only contributing to 40% of all staff while interns had the lowest output with 10% of all consultations while contributing to 15% of the staff compliment.

Table 3 describes the PPH for various clinician and shifts factors. The overall median PPH was 0.7 (IQR 0.5-1.0). There was significant variance between the clinician categories (p<0.001) with medical officers having the highest median PPH (PPH=0.8) and interns the lowest (PPH=0.4). Medical officer locums, as a subcategory, had the highest overall PPH (PPH=0.9).

There was a significant difference in PPH between the different combined shift types (p<0.001) with the PPH for the day and night shifts being 0.6 and 0.9 respectively. This similar increase in PPH during night shifts was noted for the registrars, and community service medical officer categories. The medical officers had no significant difference between any shift type and were the most consistent. There was also a combined increase in median PPH for weekdays vs weekend shifts (PPH=0.6 vs 0.8, p=0.021). Shift duration did not influence the overall PPH (p=0.228) with only the community service medical officers and
Table 1
A summary of shift characteristics (n=1 289).

| Clinician gender | n (column %) |
|------------------|--------------|
| Male             | 604 (47)     |
| Female           | 685 (53)     |

| Clinician category | n (column %) |
|--------------------|--------------|
| Registrar          | 189 (15)     |
| Medical officer (MO) | 511 (40)   |
| Community service MO | 397 (31)  |
| Intern             | 192 (15)     |

| Primary employment | n (column %) |
|--------------------|--------------|
| Emergency centre   | 1 090 (85)   |
| Different department | 71 (6)   |
| Locum              | 128 (10)     |

| Team allocation | n (column %) |
|-----------------|--------------|
| Core team       | 873 (68)     |
| Additional      | 416 (32)     |

| Shift category | n (column %) |
|----------------|--------------|
| Weekday morning (10 hours) | 398 (31) |
| Weekday afternoon (8 hours) | 350 (27) |
| Weekday night (10 hours) | 254 (20) |
| Weekend day (12 hours) | 167 (13) |
| Weekend night (12 hours) | 120 (9) |

| Cumulative shifts | n (column %) |
|-------------------|--------------|
| 1 shift | 474 (37) |
| 2 shifts | 262 (20) |
| 3 shifts | 166 (13) |
| 4 shifts | 120 (9) |
| 5 shifts | 108 (8) |
| 6 shifts | 76 (6) |
| >6 shifts | 83 (7) |

Table 2
A description of triage acuity and mean disposition time for each clinician category.

| Total | Registrar | Medical officer | Community service MO | Intern |
|-------|-----------|-----------------|----------------------|--------|
| N (row %) |
| Clinicians | 111 | 17 (15) | 46 (41) | 19 (17) | 29 (26) |
| Shifts | 1 289 | 189 (15) | 511 (40) | 397 (31) | 192 (15) |
| N (row %) |
| Patients | 9 668 | 1 383 (14) | 4 262 (44) | 3 115 (32) | 908 (10) |
| N (column %) |
| Per triage category | | | | |
| Red | 432 (4) | 93 (7) | 202 (5) | 111 (4) | 26 (3) |
| Orange | 4 534 (47) | 688 (50) | 2 061 (48) | 1 316 (42) | 469 (52) |
| Yellow | 4 163 (43) | 505 (36) | 1 832 (43) | 1 461 (47) | 365 (40) |
| Green | 539 (6) | 97 (7) | 167 (4) | 227 (7) | 48 (5) |
| h/cm (SD) |
| Mean time to disposition | 3:00 (4:07) | 3:25 (4:22) | 3:07 (4:11) | 2:37 (3:56) | 3:11 (3:59) |
| Per triage category | | | | |
| Red | 4:45 (5:23) | 4:52 (5:08) | 5:03 (5:57) | 4:00 (5:38) | 5:20 (6:37) |
| Orange | 2:52 (4:49) | 4:24 (4:58) | 2:45 (4:45) | 2:43 (4:56) | 2:57 (4:27) |
| Yellow | 2:08 (2:54) | 2:18 (3:03) | 2:21 (3:01) | 1:47 (2:41) | 2:18 (2:51) |
| Green | 1:09 (1:58) | 0:56 (1:12) | 1:28 (2:40) | 0:59 (1:26) | 1:15 (2:26) |

decline in the first three quarters (PPH=0.5) but then had a median of 0 during the last quarter of their shifts. Fig. 1 depicts the overall intra-shift variance graphically.

The association between EC workload metrics and overall PPH is depicted in Fig. 2. A significant positive association was found between the overall PPH and the number of patients waiting at the beginning of the shift (Coef. 0.003, p<0.001, 95%CI 0.002 to 0.004). Average numbers of boarders in the EC during the shift (Coef. -0.003, p=0.003, 95%CI -0.005 to -0.002) and new patients arriving during a shift (Coef. -0.002, p<0.001, 95%CI -0.002 to -0.001) were significantly negatively associated with PPH. There was no significant association between PPH and total number of patients in the EC during a shift (Coef. 0.0002, p=0.69, 95%CI 0.0008 to 0.001).

Discussion

This study, being one of the first to describe clinician output in a LMICs, demonstrates a significantly lower overall PPH as described in high-income countries. The American College of Emergency Physicians claim that even though PPH rates as high as 2.3 - 2.8 have been recognised in the past, considering the increased workload and patient complexity and acuity, customer expectations, workload factors such as crowding and boarders, and risk management a PPH of 1.8 to 2.8 is probably more realistic currently [7]. This is around 2.5 times higher than the overall PPH of 0.7 described in this study. Individual clinician’s output, however, can be influenced by several community factors including burden of disease, age, demographics, hospital factors including level of care provided by the hospital, onsite resources, inpatient bed availability, EC factors including staffing, referral pathways, capacity and clinician factors [9]. It is also imperative to realise that clinician output does not reflect overall productivity or an individual clinician’s value contribution as there are certain tasks and functions that are intangible and difficult to quantify, for example nursing intubated patients in the EC for lengthy periods. The use of PPH to quantify clinician output is therefore questionable and probably not appropriate to estimate value but rather useful and necessary for staff scheduling and surge planning. Even though RVUs has become a more commonly used metric to measure clinician output as it helps to control for patient complexity, both PPH and RVUs are imperfect measures as they fail to incorporate the unmeasurable contributors to patient care [8].

Literature has shown that clinician output is higher during shorter shifts (8-hour vs 12-hour), and during daytime [11,12]. Pines et al.
Table 3
A description of PPH for each shift factor and clinician category (median PPH (IQR)).

| Shift factors | Combined | Registrar | Medical officer | Community service MO | Intern | Employment Category |
|---------------|----------|-----------|-----------------|-----------------------|--------|---------------------|
|               | p-value  | <0.001    | 0.8 (0.6-1.1)   | 0.7 (0.5-1.1)         | 0.4 (0.3-0.6) | 0.5 (0.4-1.0)       |
| Overall       | 0.7 (0.5-1.0) | 0.7 (0.5-0.9) | 0.8 (0.6-1.1)   | 0.7 (0.5-1.1)         | 0.4 (0.3-0.6) | 0.5 (0.4-1.0)       |

- **Shift type**
  - Weekday morning: 0.6 (0.4-0.9) vs. 0.5 (0.4-0.7), p-value <0.001
  - Weekday afternoon: 0.6 (0.4-0.9) vs. 0.7 (0.4-0.9), p-value <0.001
  - Weekday night: 0.9 (0.6-1.2) vs. 0.8 (0.5-1.1), p-value <0.001
  - Weekend day: 0.7 (0.4-1.0) vs. 0.8 (0.5-0.9), p-value <0.001
  - Weekend night: 0.9 (0.7-1.1) vs. 0.8 (0.6-1.0), p-value <0.001

- **Shift duration**
  - 8 hours: 0.6 (0.4-0.9) vs. 0.6 (0.4-0.9), p-value 0.021
  - 10 hours: 0.7 (0.5-1.0) vs. 0.7 (0.5-1.0), p-value 0.021
  - 12 hours: 0.8 (0.5-1.1) vs. 0.8 (0.6-1.0), p-value 0.021
  - 16 hours: 0.5 (0.4-0.7) vs. 0.5 (0.4-0.7), p-value 0.021

- **Cumulative shifts**
  - 1 shift: 0.6 (0.4-1.0) vs. 0.7 (0.4-1.0), p-value <0.001
  - 2 shifts: 0.7 (0.5-1.0) vs. 0.7 (0.5-0.9), p-value <0.001
  - 3 shifts: 0.6 (0.4-1.0) vs. 0.7 (0.4-1.2), p-value <0.001
  - 4 shifts: 0.7 (0.4-0.9) vs. 0.6 (0.4-1.0), p-value <0.001
  - 5 shifts: 0.8 (0.5-1.1) vs. 0.8 (0.5-0.9), p-value <0.001
  - 6 shifts: 0.8 (0.6-1.1) vs. 0.8 (0.6-1.0), p-value <0.001
  - >6 shifts: 0.8 (0.6-1.2) vs. 0.9 (0.6-1.1), p-value <0.001

- **Intra shift variance**
  - 1st quarter: 1.0 (0.5-1.5) vs. 1.0 (0.5-1.5), p-value <0.001
  - 2nd quarter: 0.8 (0.5-1.2) vs. 0.8 (0.4-1.2), p-value <0.001
  - 3rd quarter: 0.5 (0.3-1.0) vs. 0.5 (0.3-1.0), p-value <0.001
  - 4th quarter: 0.3 (0.0-0.7) vs. 0.3 (0.0-0.7), p-value <0.001

(2020) showed perceived workload and operational stressors such as patient complexity and acuity, workload factors such as boarders and new patient arrivals, to be higher overnight [13]. It is however interesting to find that the clinicians’ output in this study was not affected by shift length and were in fact significantly higher during weekend shifts and night shifts. Jeammonod et al. (2009) found that senior (third year) residents had higher PPH rates on night shifts as opposed to junior residents, presumably due to the improved ability to process the lower acuity patient that presented overnight [14]. The reasons for the higher PPH rate during night shifts in this study is likely multifactorial and requires further assessment.

Clinician role has been recognised as a driver of productivity and output [8]. At MPH, locum clinicians, who are exclusively involved in patient care and generally assigned to lower acuity areas, were shown to have the highest output over MPH EC core clinicians, who also attend to administrative (non-clinical) tasks, patient flow and complex patient hand overs. Joseph et al. (2018) found that residents who received more patient hand overs during shift change, tend to consult fewer patients during their shift. This was significant for the second-year residents who generally also attended to higher acuity patients and resulted in a much lower output [15]. Brennan et al. (2007) also postulated that the lower increase in productivity between senior residents’ years was due to the increased unmeasurable non-clinical responsibilities [16]. Which could potentially explain why EC clinicians had lower output than locums, and that registrars had lower output than the medical officers.

There was an obvious decline in output during the course of a shift, in keeping with previous research [12,14], which plunged in the last quarter with PPH declining to zero for the intern group. This is an important finding to consider when scheduling clinicians and considering shift length and overlap, peak patient presentation times and shift scheduling models [8]. Even though output decreased within a shift, there was a significant increase shown with consecutive shifts. Jeammonod et al. (2009) proposed this to be due to an increasing familiarity with the environment and patient [17]. The thought that environment familiarity improves productivity may further be illustrated by the fact that in our study medical officers and community service medical officers, who generally stay in the department for a longer period, produced a higher overall PPH than registrars and interns, who generally rotate through the EC for shorter periods. Similarly, Joseph et al. (2018) showed improved intern productivity with time spent in the EC rather than their year of training [18].

Although the average total patient volume in the EC did not have a significant impact on clinician output in both this study and in previous studies [14], there was a significant negative correlation between the average number of boarders in the EC and clinician output. Access block and disruptions to the outflow of patients from the EC has been shown to drain hospital resources and impair the EC’s ability to care for new seriously ill or injured patients [19]. The presence and number of boarders have been shown to be the most consistent cause of delays in EC patient care with access block having a significant relationship to EC crowding and EC length of stay [3]. There was however a positive correlation between clinician output and patients waiting to be seen at the start of a shift.

There is a paucity of data in LMICs describing emergency clinician output and the results of this study can be used to generate hypotheses and could form the basis for future studies. Even though this study was one of the first in a LMIC, the significance of the results could be limited by the fact that this was a single centre and potentially only reflecting local practice. Vukmir et al. (2010) showed that PPH was lower for smaller centres seeing 1 500 or less patients per annum compared to larger centres that saw 45 000 or more patient per annum [20]. Another
limitation is that not all factors that could have influenced clinician output were assessed, such as clinician experience (years post qualification for registrars and medical officers) and time since employment (familiarity with the EC environment). Confounding factors should also be modelled in future research.

Future research should assess potential reasons for the low PPH described and subsequent studies should focus on the cost-effectiveness of quality improvement interventions. A multicentre study should confirm whether the results are generalisable and determine the key drivers behind clinician output in a low resource setting.

**Conclusion**

This study describes a relatively low clinician output as compared to evidence from high-income countries and has highlighted several associations with various shift, clinician, and workload factors. Clinician output was negatively associated with the number of boarders in the EC but positively associated with the number of patients waiting at the start of each shift. Both PPH and RVUs are regarded as imperfect measures of productivity as they fail to incorporate the unmeasurable contributions to patient care and non-clinical workload. The results from this study...
will form the basis of quality improvement interventions to improve patient throughput and will inform staff scheduling and surge planning strategies.

Dissemination of Results
The results have been disseminated to the respective Emergency Centre and Hospital managers, as well as to the Faculty of Emergency Medicine Cape Town.

Authors’ Contributions
Authors contributed as follows to the conception or design of the work; the acquisition, analysis, or interpretation of data for the work; and drafting the work or revising it critically for important intellectual content: MH contributed 45%; CH 35%; and MM 20%. All authors approved the manuscript to be published and agreed to be accountable for all aspects of the work.

Declaration of Competing Interest
Both CH and MM are editors of the African Journal of Emergency Medicine. CH and MM were not involved in the editorial workflow for this manuscript. The African Journal of Emergency Medicine applies a double blinded process for all manuscript peer reviews. The authors declared no further conflicts of interest.

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