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Mortality Outcomes in Task-Sharing for Emergency Care: Impact of Emergency Physician Supervision on Non-Physician Emergency Care in Rural Uganda

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ABSTRACT

Objectives

Emergency care capacity is limited by physician shortages in low-income countries like Uganda. Delegating tasks to more narrowly trained cadres — "Task-sharing" — of non-physician clinicians is a proposed solution. This study assesses whether different levels of emergency medicine physician supervision of non-physician clinician care impact three-day mortality.

Methods

Retrospective analysis of an emergency care non-physician clinician training program in rural Uganda included three cohorts: "Direct Supervision" (2009-2010): emergency medicine physicians supervised all non-physician clinician care; "Indirect Supervision" (2010-2015): non-physician clinicians consulted emergency medicine physicians as needed; "Independent Care" (2015-2019): non-physician clinician care without emergency medicine physician supervision. Multivariable logistic regression analysis of three-day mortality was performed with patients stratified by supervision cohorts and abnormal vital signs.

Results

38,344 ED visits met inclusion criteria. Overall mortality was significantly lower in the "Independent Care" than the "Direct Supervision" cohort (2.7% vs. 3.8%, p<0.001), but so too were the rates of patients presenting with ≥3 abnormal vitals (10.2% vs. 25.2% to p<0.001). After controlling for the mortality associated with abnormal vitals, both "Indirect Supervision" and "Independent Care" were independently associated with increased mortality compared to "Direct Supervision" (Indirect Odds Ratio (OR)=1.49 [95%CI 1.07 - 2.09], Independent OR=1.76 [95%CI 1.09 - 2.86]). Sensitivity analysis showed that this mortality benefit was

restricted to the 13.8% of patients with ≥3 abnormal vitals, with all other patients showing no significant independent association between supervision cohort and mortality.

Conclusion

Direct emergency medicine physician supervision of emergency care non-physician clinicians is independently associated with reduced overall mortality. This benefit appears restricted to the highest risk patients based on abnormal vitals. That over 85% of patients have equivalent mortality outcomes with independent non-physician clinician emergency care suggests a synergistic model providing variable levels of emergency medicine physician supervision and care based on acuity could safely address staffing shortages.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- Data from the largest and longest standing emergency care patient database with mortality outcomes, as well as only database of emergency care outcomes for non-physician clinician care, published to date in Africa.
- The transition from physician supervision to independent non-physician clinician care generates a unique natural experiment.
- This is a single site study conducted at a rural, district-level hospital.
- Patient-level physician supervision data is lacking.
- The logistic regression imperfectly controls for changing baseline of population health during the study period.

INTRODUCTION

Global recognition of the need to develop emergency care is growing. (1,2) In low- and middle-income countries LMICs, physician shortages make the provision of medical care and in particular emergency care problematic, with the greatest challenge centered in Sub-Saharan Africa. (3–5) Emergency care needs remain largely unmet throughout many LMICs, including Uganda. (5–8) Based on the estimate that 57% of deaths occurring in low-income countries are from conditions treatable with emergency care, approximately 160,000 Ugandans' lives could have been saved by provision of emergency care in 2019. (9,10) Emergency care in Uganda is largely limited by physician shortages, as there are 1.68 physicians per 10,000 people, amongst the lowest rates worldwide. (11). Uganda has placed a priority on developing emergency care over the next five years, estimating that 454 specialist emergency care physicians will be required by 2025. (12) Emergency care specialty training in Uganda began in 2017 and currently certifies between five and 10 Ugandan emergency medicine specialists per year.(13) This leaves an enormous training gap with 45 and 90 years of training needed to produce emergency medicine specialists to meet the projected five-year staffing demands.

One solution to address this shortage that has been widely advocated and implemented in SSA is "task-sharing," or delegating tasks to more narrowly trained cadres of new or existing providers, often non-physician clinicians. (14–20) The World Health Organization advocates for non-physician clinicians that are "adequately trained, supported and supervised". (18,19) Though non-physician clinicians are currently providing surgical specialty, obstetric, and HIV care throughout SSA (21–27), there has been limited application of non-physician clinician cadres to offset emergency care shortages. (20,28,29) High-income countries have compensated for regionally inadequate physician numbers and uneven distribution of emergency physicians by

adopting physician supervised non-physician clinicians in larger emergency units and in some cases non-physician clinician practice with remote physician supervision in smaller rural hospitals. (30–33) Data and protocols to guide implementation of emergency care non-physician clinician training and practice in LMICs, where emergency medicine is largely newly developing, and emergency medicine physicians are typically not available, is highly limited.

Few articles exist addressing training of non-physician clinicians for roles in the African acute care settings outside of trainings focused on specific obstetric, surgical or anesthesia procedures (34–37), while others find that emergency and acute care training is lacking in non-physician clinician education in many SSA countries including Uganda. (34,38) While our research group has published on an emergency care non-physician clinician training program and its associated outcomes, we are not aware of any additional studies documenting a comprehensive emergency care non-physician clinicians training program in a LMIC. (29,39–44) There are documentation a few short-courses designed to teach non-physician clinicians emergency care skills in SSA. (45–48) Consistent with this limited evidence base, no standards exist describing if, when or how to transition to reduced supervision or independent non-physician clinician care following initial training. The impact of transitioning to decreased levels of supervision on quality of non-physician clinician care and patient outcomes is therefore unknown. This represents a major limitation in the ability to implement non-physician clinician training, supervision and uptake into health systems in a safe, effective and evidence-based manner.

While health systems are evolving in Uganda over the last decade so too is the health of the general population. Uganda's national crude death rates decreased by 63% across all age groups (10.2/1000 in 2009 to 6.4/1000 persons in 2019) during the study period. (49) Likewise,

under-five mortality decreased by approximately 38,000 deaths per year (112,747 in 2009 to 74,053 in 2019). (49) Concurrently, life expectancy increased by 6.8 years and rates of malaria and HIV infection decreased. (49)

Emergency care has been delivered by non-physician clinicians in Uganda since 2009 in a training program that has transitioned from directly supervised to independent non-physician clinician care. The objective of this study was to test the hypothesis that increasing levels of emergency medicine physician supervision for three cohorts of non-physician clinicians were independently associated with reduced three-day patient mortality. Sensitivity analysis was performed to attempt to define which patients had mortality outcomes impacted by physician supervision.

METHODS

Description of Study Site

All data comes from the emergency unit at Karoli Lwanga Hospital, a rural district hospital located in the town of Nyakibale in the Rukungiri District of southwest Uganda. The hospital has a six-bed emergency unit that opened in 2008 and treats 300 to 700 patients per month arriving between 8:00 am and midnight every day of the year. Since 2009, the emergency unit has been staffed by non-physician clinicians who received training from emergency medicine physicians working with Global Emergency Care. The non-physician clinicians are nurses who have completed a two-year advanced training course in emergency care described in detail elsewhere by Hammerstedt et al (29). While the course is currently administered in conjunction with Mbarara University of Science and Technology, the non-physician clinicians in this cohort study were trained as part of the pilot program that began through a collaboration

between GEC and Karoli Lwanga Hospital. Global Emergency Care (GEC), a US-based 501(c)[3] non-governmental organization, has run a two-year emergency care specialty non-physician clinician training program since 2009, and currently does so in collaboration with Mbarara University of Science and Technology (MUST).

Supervision of the non-physician clinicians changed over time generating three cohorts: "Direct Supervision", "Indirect Supervision" and "Independent Care". "Direct Supervision" occurred from November 2009 - April 2010 when a single US-trained emergency medicine physician practicing with a Ugandan license was on site every day and directly supervised non-physician clinician care and supplemented with clinical care in a model similar to US residency training. "Indirect Supervision" occurred from July 2010 - November 2015. During this period a volunteer US-trained emergency medicine physician was on site for approximately 85% of the weeks; however, they were present in a teaching role only and provided no direct patient care. They were available for consultation on an ad hoc basis and consultation was based on non-physician clinician discretion. "Independent Care" occurred from December 2015 - December 2019, and non-physician clinicians provided clinical care without any onsite emergency medicine physician. During the entire study period, no Ugandan physicians were assigned to the emergency unit. Hospital physicians were available in a similar manner throughout the study period for consultation for patients who required surgery, did not respond to initial treatments, or in whom there was considerable diagnostic uncertainty. Throughout the study period, non-physician clinicians admitted patients to the same hospital medical and surgical wards, which were staffed by Ugandan physicians with standard levels of training and no connection to GEC. Resource availability was constant over the study period and with resource utilization by clinicians in this emergency unit described in detail elsewhere. (39)

Patient and Public Involvement

The non-physician clinician training program was originally developed in response to several years of clinical emergency medicine experience and ongoing healthcare staffing shortages in Uganda. The positive response of patients, staff and administrators at Karoli Lwanga Hospital to the training program and their interest in improving patient care led to ongoing research and program evaluation. Patients and the public were not involved in the design of the study; however, outcome measures are explicitly patient-oriented. Results have been and will continue to be disseminated through open access publications to allow local clinicians, administrators, policymakers and researchers to benefit.

Data Collection

GEC maintained a group of trained research associates who prospectively collected quality assurance data on all Karoli Lwanga Hospital emergency unit patient visits. Collected data included demographics, vital signs, laboratory and radiology testing, disposition, as well as three-day follow-up vital status (mortality) for all admitted and discharged patients. On the third day following initial evaluation in the emergency unit, patients admitted to the hospital were visited in person, and patients discharged from the emergency unit or ward were contacted via phone. This follow-up protocol included seven consecutive days of calling all patients on the phone (if they had a phone) before considering them lost to follow-up and is described in detail elsewhere. (29) Ethics approval for the quality assurance database and waiver of consent was obtained through the Institutional Review Board at Mbarara University of Science and Technology (No. 11/08-12). Trained research assistants entered data using Microsoft Excel from 1 January 2010 – 23 March 2012, and Microsoft Access from 24 March 2012 – 31 December 2019.

Data Analysis

A cohort study was done using retrospective analysis of prospectively collected data abstracted from the Karoli Lwanga Hospital emergency unit quality assurance database, including all consecutive patients presenting to the emergency unit from November 2009 until December 2019. All patients missing age, gender, disposition and three-day follow up were excluded from analysis. Patients who were dead on arrival (lacked vital signs with no resuscitation or interventions attempted) and patients who were transferred or left against medical advice did not receive follow-up by protocol and thus were also excluded from analysis. All other patients of all ages and dispositions were included. Vital signs were taken for all patients, but the inconsistent availability of pediatric sphygmomanometers meant that blood pressures were missing for 89% of children under 5 and 47% of children aged 5-12, as compared to 3% missing in all other age groups. To control for this effect, all patients aged 12 or less that had missing blood pressure were coded as normal for analysis. No other missing variables were coded as normal, and no other data was imputed. Data was abstracted, cleaned, and analyzed by a single researcher (BR) using Stata 16.1 (StataCorp, College Station, TX). No power or sample size calculations were performed as all available records were included in analysis.

Continuous variables were tested for significance using one-way ANOVA and proportions were compared using chi-squared. A multiple variable logistic regression model was developed to test the significance of associations between independent variables and mortality in emergency unit patients. Because only two months of data existed for 2009, and three months of data were missing for 2010, the years 2009 and 2010 were both coded as 2010 for the continuous "Year" variable included in that model. Eleven variables were included for the final model meeting the minimal criterion of ten events per variable (n=1,119 events overall).(50) Area

Under Receiver Operating Characteristics Curve (AUROC), Hosmer-Lemeshow Goodness of Fit, and Brier score were all calculated for this model.

RESULTS

Overall, 49,804 patient visits occurred from 2009 - 2019, and 38,344 met criteria for inclusion for analysis. Inclusion and exclusion criteria are shown in Figure 1 below.

Figure 1: Patient Flow Diagram

Patient characteristics stratified by cohorts of patients receiving non-physician emergency care with different levels of emergency medicine physician supervision (as described in Methods above) are shown in Table 1 below.

Table 1: Patient Characteristics

Characteristic	Direct Supervision Cohort (n=2017)	Indirect Supervision Cohort (n=21210)	Independent Care Cohort (n=15111)	P-value
Age, mean (SD)	25.8 (23.2)	28.8 (24.1)	32.9 (24.9)	< 0.001*
Age Group				
Under 5, % (n)	25.8% (521)	21.0% (4446)	14.5% (2193)	< 0.001
5-12 y.o., % (n)	7.4% (149)	7.7% (1622)	7.3% (1103)	
12-18 y.o., % (n)	8.2% (165)	8.3% (1750)	7.4% (1112)	
18-64 y.o., % (n)	49.6% (1000)	51.9% (11004)	56.6% (8550)	
> = 65 y.o., % (n)	9.0% (182)	11.3% (2394)	14.3% (2153)	
HIV-positive (known status or newly diagnosed), % (n)	1.7% (35)	5.6% (1185)	6.9% (1047)	< 0.001
Malaria parasites on blood smear, % (n)	22.8% (460)	18.4% (3898)	5.6% (846)	< 0.001
Gender - Female, % (n)	46.5% (939)	46.1% (9789)	46.6% (7047)	0.64

Complete Vital Signs, %(n)	87.2% (1758)	87.5% (18571)	90.3% (13652)	<0.001
Vital Sign Abnormalities				
Hypoxia, % (n)	12.4% (250)	11.9% (2524)	12.7% (1917)	0.84
Tachypnea, % (n)	51.3% (1035)	43.1% (9140)	27.7% (4185)	<0.001
Bradycardia, % (n)	1.8% (37)	4.0% (856)	4.5% (673)	<0.001
Tachycardia, % (n)	31.3% (632)	18.3% (3888)	15.2% (2303)	<0.001
Hypothermia, % (n)	35.9% (724)	27.4% (5806)	29.4% (4448)	<0.001
Febrile, % (n)	21.1% (426)	15.6% (3300)	13.6% (2052)	<0.001
Hypotension, % (n)	19.6% (396)	11.9% (2533)	7.9% (1191)	<0.001
Number of abnormal vital signs				
0 or 1, % (n)	46.2% (932)	61.3% (13001)	69.0% (10429)	<0.001
2, % (n)	28.6% (577)	23.4% (4968)	20.8% (3136)	
3 or more, % (n)	25.2% (508)	15.3% (3247)	10.2% (1546)	
* ANOVA used for significance test; all others use chi-squared				

There were significant differences in every characteristic across the cohorts except for gender and hypoxia. As the study progressed, fewer pediatric patients, more adult and elderly patients, fewer patients with malaria, more patients with HIV, more complete vital signs and fewer abnormal vital signs were present. The rates of missing vital sign data were: blood pressure 2.0%, respiratory rate 4.9%, pulse oximetry 5.7%, heart rate 1.6%, and temperature 2.1%.

The overall three-day mortality across the program from 2009-2019 was 3.1% (1,199 deaths overall). Overall, mortality increased significantly ($p<0.001$) and monotonically based on the number of abnormal vital signs patients had on presentation from zero or one (1.31%, n=319 deaths in 24,362 patients), to two (3.97%, n=345 deaths in 8,681 patients) to three or more (10.1%, n=535 deaths in 5,301 patients). A clear trend towards lower mortality and a lower

proportion of patients presenting with abnormal vital signs existed over time and is shown in Figure 2.

Figure 2: Mortality and vital sign abnormalities 2009 - 2019

Crude mortality decreased significantly across supervision cohorts ("Direct Supervision": 3.8%, "Indirect Supervision": 3.4%, "Independent Care": 2.7%, $p<0.001$). Conversely, the proportion of patients presenting with zero abnormal vitals increased across supervision cohorts and those presenting with three or more abnormal vital signs decreased (values in Table 1, visualized in Figure 2).

Unadjusted mortality across supervision cohorts was stratified by the number of abnormal vital signs is displayed visually in Figure 3 below (values in Appendix 1).

Figure 3: Mortality stratified by number of abnormal vital signs across supervision cohorts

As illustrated in Figure 3**,** the mortality for the "Indirect Supervision" and "Independent Care" cohorts were very similar, while "Direct Supervision" had higher mortality in patients with zero or one abnormal vital sign and lower mortality in patients with three or more abnormal vital signs. Confidence intervals were wide, but both differences (increased and decreased mortality) achieved statistical significance (see Appendix 1).

Given the changing baseline in patient mortality and prevalence of vital sign abnormalities, a logistic regression model was developed to determine whether physician supervision of non-physician clinician care was independently associated with increased or decreased mortality for emergency unit patients. The results of this model are displayed in Table 2 below.

Table 2: Logistic Regression

Characteristic	All Patients (n=33,996)			Zero or One Abnormal Vital (n=21,096)			Two Abnormal Vitals (n=7,940)			Three or More Abnormal Vitals (n=4,960)		
	OR	95% CI	P-Value	OR	95% CI	P-Value	OR	95% CI	P-Value	OR	95% CI	P-Value
Age Group												
Under 5	1.23	1.00 - 1.52	0.046	1.32	0.87 - 2.01	0.189	1.73	1.19 - 2.53	0.005	0.87	0.63 - 1.19	0.377
5-12 y.o.	0.79	0.56 - 1.10	0.16	0.94	0.49 - 1.81	0.853	1.07	0.58 - 1.98	0.834	0.60	0.36 - 1.00	0.048
12-18 y.o.	0.49	0.33 - 0.74	0.001	0.55	0.25 - 1.20	0.132	0.29	0.11 - 0.81	0.017	0.60	0.35 - 1.05	0.074
18-64 y.o.	REF			REF			REF			REF		
≥65 y.o.	1.58	1.32 - 1.90	<0.001	2.84	1.98 - 4.08	<0.001	1.74	1.25 - 2.42	0.001	1.05	0.80 - 1.37	0.748
HIV positive	2.23	1.80 - 2.75	<0.001	4.01	2.62 - 6.13	<0.001	2.35	1.57 - 3.53	<0.001	1.65	1.23 - 2.20	0.001
Malaria smear positive	0.98	0.80 - 1.19	0.81	1.45	0.98 - 2.15	0.064	1.21	0.85 - 1.71	0.291	0.70	0.52 - 0.94	0.019
Female gender	0.68	0.59 - 0.79	<0.001	0.65	0.49 - 0.87	0.004	0.64	0.50 - 0.83	0.001	0.72	0.58 - 0.88	0.001
Year	0.94	0.90 - 0.99	0.019	0.91	0.83 - 1.01	0.079	0.96	0.87 - 1.05	0.343	0.95	0.89 - 1.03	0.215
Vital Signs												
Hypoxic	4.51	3.90 - 5.23	<0.001	3.25	1.67 - 6.33	0.001	2.52	1.62 - 3.91	<0.001	3.37	2.62 - 4.33	<0.001
Tachypnea	2.16	1.85 - 2.53	<0.001	1.87	1.24 - 2.82	0.003	1.04	0.68 - 1.58	0.858	2.07	1.47 - 2.90	<0.001
Heart Rate												
Bradycardic	2.20	1.73 - 2.80	<0.001	0.97	0.23 - 4.01	0.965	1.10	0.63 - 1.92	0.737	1.82	1.31 - 2.53	<0.001
Normal	REF			REF			REF			REF		
Tachycardic	1.68	1.41 - 1.99	<0.001	2.99	1.69 - 5.31	<0.001	0.65	0.39 - 1.08	0.097	1.34	1.04 - 1.73	0.022
Temperature												
Hypothermic	2.22	1.91 - 2.58	<0.001	2.20	1.50 - 3.23	<0.001	1.25	0.80 - 1.95	0.325	1.31	0.99 - 1.74	0.059
Normal	REF			REF			REF			REF		

Febrile	0.81	0.66	-	1.01	0.06	1.67	0.86	-	3.26	0.131	0.52	0.30	-	0.88	0.016	0.50	0.37	-	0.69	<0.001
Hypotensive	2.01	1.71	-	2.37	<0.001	1.49	0.59	-	3.78	0.398	N/A					1.67	1.33	-	2.09	<0.001
Supervision Cohort																				
Direct (2009-2010)	REF					REF					REF					REF				
Indirect (2010-2015)	1.49	1.07	-	2.09	0.019	1.12	0.54	-	2.33	0.768	1.17	0.65	-	2.11	0.601	1.75	1.08	-	2.85	0.024
Independent (2015-2019)	1.76	1.09	-	2.86	0.021	1.33	0.49	-	3.63	0.576	1.26	0.53	-	3.00	0.602	2.14	1.05	-	4.34	0.036

In this model, all abnormal vital signs, age < 1 year old and ≥ 65, HIV positivity and male gender were all significantly associated with increased mortality. Female gender, year (as a continuous variable between 2009 and 2019) and age between 12 and 18 were associated with decreased mortality. After controlling for these factors, increased mortality was independently associated with "Indirect Supervision" (Odds Ratio (OR)=1.49 [95%CI 1.07 - 2.09], and "Independent Care" (OR=1.76 [95%CI 1.09 - 2.86]) as compared to "Direct Supervision". This model was well-calibrated (brier score 0.025), discriminated well between patients at risk for our outcome of interest (death) (AUROC 0.81) and was not over-fitted (Hosmer-Lemeshow 0.28).

As a sensitivity analysis, we looked at patients grouped by number of abnormal vital signs (Table 2). Patients with zero, one or two abnormal vital signs had no significant mortality association between mortality and supervision cohorts. Patients with three or more abnormal vital signs had increased mortality associated with "Indirect Supervision" (OR=1.75 [95%CI 1.08 - 2.85] or "Independent Care" (OR=2.14 [95%CI 1.05 - 4.34]) as compared to "Direct Supervision".

DISCUSSION

This study of a non-physician clinician emergency care training program in rural Uganda demonstrates that direct supervision by emergency medicine physicians of non-physician clinician emergency care was independently associated with reduced three-day mortality. This mortality impact was restricted to the most severely ill subset of patients – as defined by abnormal vitals – with independent non-physician clinician care having similar outcomes to care directly supervised by emergency medicine physicians for the vast majority of patients. These

findings are consistent with a prior study by our author group showing the mortality benefit for direct emergency medicine physician supervision was restricted to the most severely ill subset of children under 5 years of age (42). We are not aware of any other studies addressing mortality rates of patients cared for by emergency care specialty trained non-physician clinicians in similar LMIC settings. This finding has potentially profound implications for policy to maximize workforce potential in the rapidly developing field of emergency care in Uganda and in similar settings.

One of the fundamental challenges of our analysis was the rapidly changing background of the health system in Uganda during the study period (2009-2019). Many of the most profound shifts seen in our study likely reflect the overall changes in Ugandan health care. As shown in Figure 2, overall mortality significantly ($p<0.001$) decreased by almost 70% during the study period. While impressive, this finding is consistent with the 63% reduction in national crude death rate during the study period (49). Similarly, we saw many demographic shifts in our population over time (Table 1) including fewer emergencies in children under 5, more elderly patients and reduced rates of malaria. Again, these are consistent with Ugandan national trends over that time period.(49) Figure 2 also showed an increasingly healthy patient population as defined by being more likely to have normal vital signs and less likely to have abnormal vital signs. The proportion of patients receiving complete vitals increased over time, so this effect is unlikely due to changing data collection but rather by population level trends in overall health and/or earlier emergency care-seeking behavior.

Our initial attempts to control for these changing baselines was to group patients by their number of abnormal vital signs and mortality across cohorts (Figure 3). While this was an appealing approach given its simplicity, the findings were difficult to interpret with direct

physician supervision being associated with both significantly *decreased* mortality in the highest mortality group and significantly *increased* mortality in the lowest mortality group.

To address these internally inconsistent findings, we developed a logistic regression model for emergency unit mortality to identify the independent association between supervision and three-day mortality. Within this model, indirect supervision of non-physician clinician care and independent non-physician clinician care were both seen to have increased mortality when compared to direct supervision of non-physician clinician care (Indirect OR=1.49 [95%CI 1.07 - 2.09], Independent OR=1.76 [95%CI 1.09 - 2.86]). This is an expected finding, as no argument exists in this manuscript or elsewhere suggesting complete equality between physician and non-physician clinician training, practice or outcomes. Rather, this finding clearly highlights the importance of the scaling-up of the ongoing emergency medicine physician training efforts in Uganda to reduce mortality in emergencies nationwide.

While emergency medicine physician care for all emergency patients is ideal, the current rate of emergency medicine specialist training, health system funding, and high demand for emergency medicine specialist physicians at training institutions and in administrative roles, means that the ideal of emergency medicine specialist clinical care in emergency units throughout Uganda may be decades away from being realized. Therefore, optimizing the role of non-physician clinicians can help address the current gap between emergency care patients and providers.

Because our vital sign analysis suggested that the benefit of direct supervision was greatest in the highest-risk subset of patients, and this was consistent with prior studies showing the benefit of direct supervision was limited to severely ill pediatric patients, we performed additional sensitivity analysis stratifying by vital signs.(42) We found patients with two or fewer

abnormal vital signs had no significant reduction in mortality associated with direct supervision. Importantly, there was also no trend towards harm from direct supervision as suggested by our initial crude vital sign analysis. Patients with three or more vital sign abnormalities did have a clinically and statistically significant mortality benefit with direct emergency medicine physician supervision. We believe this finding could be used at triage to immediately identify patients most likely to receive benefit from direct emergency medicine physician clinical care or direct supervision of non-physician clinician care.

Indirect physician supervision did not clearly impact mortality in either crude vital sign or logistic regression analysis. This may stem from an underlying lack of benefit from that model or from one of several limitations in the real-world implementation of indirect supervision in the GEC model. GEC relied on volunteer emergency medicine physicians, and only had a volunteer on site for approximately 85% of the weeks of the "Indirect Supervision" cohort. These physicians did not have Ugandan medical licenses, were explicitly not permitted to provide direct care, and volunteers had differing levels of training and local expertise. Further, no standardized protocol existed to define patients for which non-physician clinicians should involve the emergency medicine physician in care. Further studies might determine if protocolized and/or consistent indirect physician supervision could provide a mortality reduction for high-risk patients similar to direct physician supervision.

In total, this manuscript shows that direct supervision of non-physician clinician care by an emergency medicine physician reduces overall mortality. We strongly support the ongoing development of emergency medicine specialty training for physicians in Uganda to help achieve the ultimate goal of providing emergency medicine physician clinical care or direct supervision for all patients. However, current emergency care staffing shortages in Uganda and elsewhere in

Sub-Saharan Africa are likely to persist for decades to come and augmenting the physician workforce with emergency care specialty-trained non-physician clinicians — who can be trained more rapidly, at a lower cost, and are more likely to work in rural areas — is a clear path forward to addressing the immediate emergency care needs faced by millions of Ugandans today.(4,19,38,51) Our analysis shows that a synergy between these groups is possible: non-physician clinicians are capable of safely delivering independent care for less severely ill patients (nearly 90% of patients in our study population) with mortality outcomes similar to care supervised directly by emergency medicine physician, while direct emergency medicine physician supervision of non-physician clinician care of the most severely ill patients can reduce mortality.

Limitations

This is a single center, retrospective study of an emergency unit database. Mortality follow-up was limited to three days. While one week and one month mortality is undoubtedly important, three-day follow-up was chosen both to minimize loss to follow-up in a setting where most patients do not have consistent ability to receive phone calls and because follow-up after three days was thought to be less reflective of outcomes related to acute care provided in the emergency unit. Inpatient mortality was affected not just by emergency unit care but also by hospital ward care. However, this care was provided similarly throughout the study, making it unlikely to bias outcomes in comparisons between cohorts. The decision to code missing blood pressures in children as normal likely biased the study towards seeing pediatric patients as lower risk. However, since those patients were predominantly clustered in the direct supervision cohort, that decision would have biased results towards the null hypothesis (no impact from direct supervision) and thus was unlikely to bias our findings overall. Lastly, there was a high

loss to follow-up in discharged patients over the duration of the study. However, with a mortality rate of 0.08% (n=7 deaths in 9,175 discharges) in those with complete follow-up, it is highly unlikely that the 8,308 discharged patients lost to follow-up represent a significant number of fatal cases excluded from our analysis. The 6.3% loss to follow-up rate for admitted and direct to theatre patients was otherwise considered adequate given the challenges of emergency unit data collection in Sub-Saharan Africa.

CONCLUSIONS

This manuscript shows that task-sharing of emergency care specialty-trained non-physician clinicians to address emergency care staffing shortages is both efficient and safe. As Uganda strives to reach the goal of consistent emergency medicine physician coverage of emergency units, operationalizing a hybrid model with emergency medicine physician supervision of otherwise independent non-physician clinician care for the sickest emergency care patients has the potential to save lives. Based on the robust evidence base we report above, the authors' recommendations are as follows:

1. Scale up emergency medicine physician development and training: The highest risk approximately 10% of patients had nearly a 50% reduction in mortality with physician involvement, and direct supervision significantly reduced overall mortality.
2. Increase capacity for emergency care NCP training: emergency care non-physician clinicians provided independent care comparable to care given with direct emergency medicine physician supervision for approximately 90% of patients over the study period.
3. Create triage protocols for early identification of the highest risk patients: in our analysis patients with hypoxia or with 3 or more abnormal vital signs are at highest risk for

mortality and most likely to derive benefit from emergency medicine physician clinical care or direct supervision of non-physician clinician care.

4. Create clear protocols and systems to provide emergency care non-physician clinicians with direct supervision in person or via phone/telehealth consultation by emergency medicine physician for critically ill and high-risk patients.

Contributorship statement:
BR, AP and MB planned the study. BR, CL analyzed the data. BR, AP, CL, PK, RL, SK, CN, SN, LF, MB interpreted the data in the local context. BR, AP, CL, RL drafted the manuscript. BR, AP, CL, PK, RL, SK, CN, SN, LF, MB revised the manuscript. AP submitted the study. BR and AP are the guarantors of the overall content.

Competing Interests: None of the authors have competing interest to disclose.

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Data sharing statement: IRB approval restricts sharing of the full data set.

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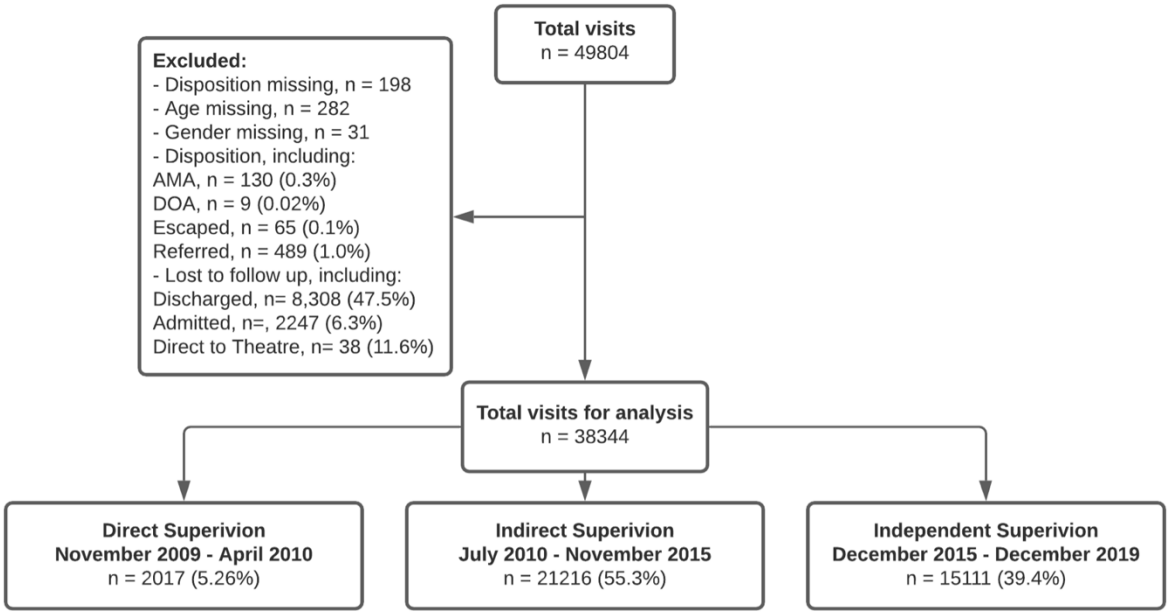

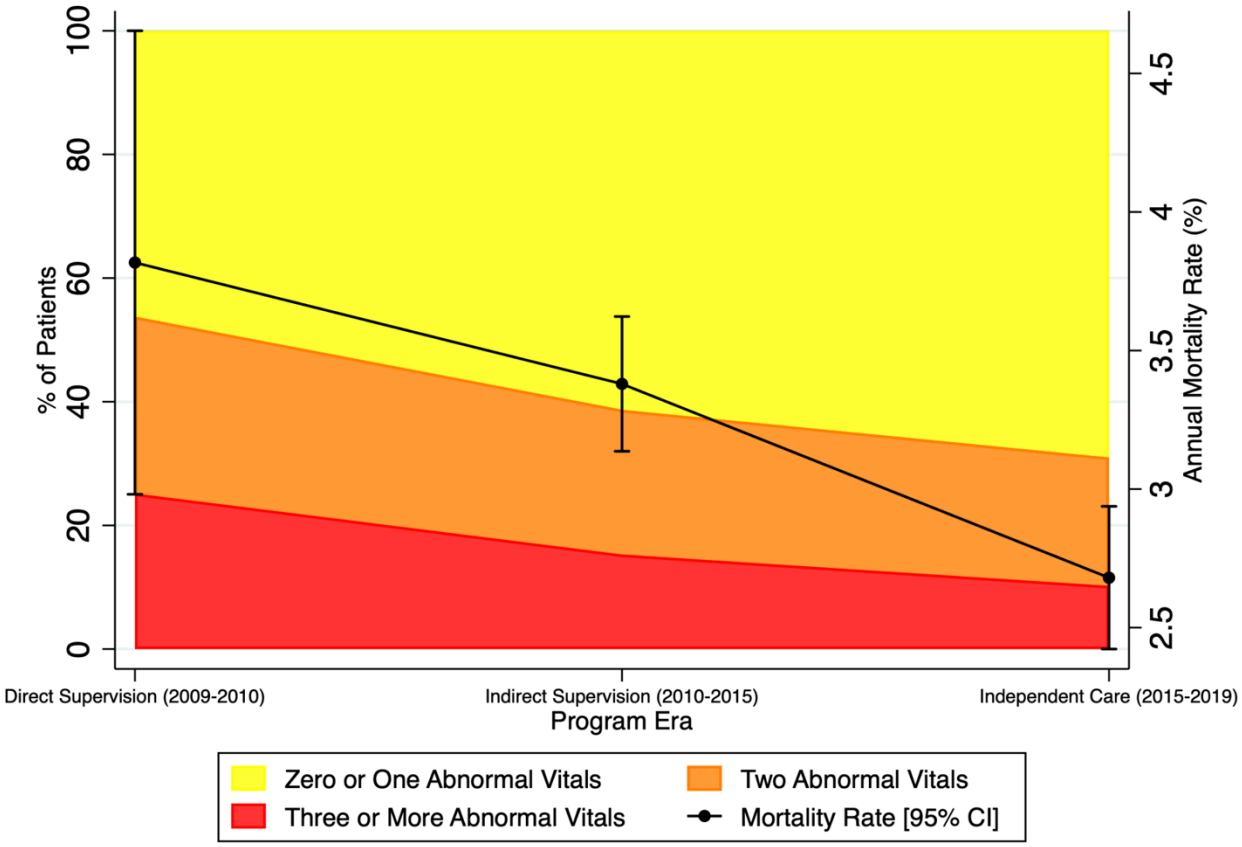

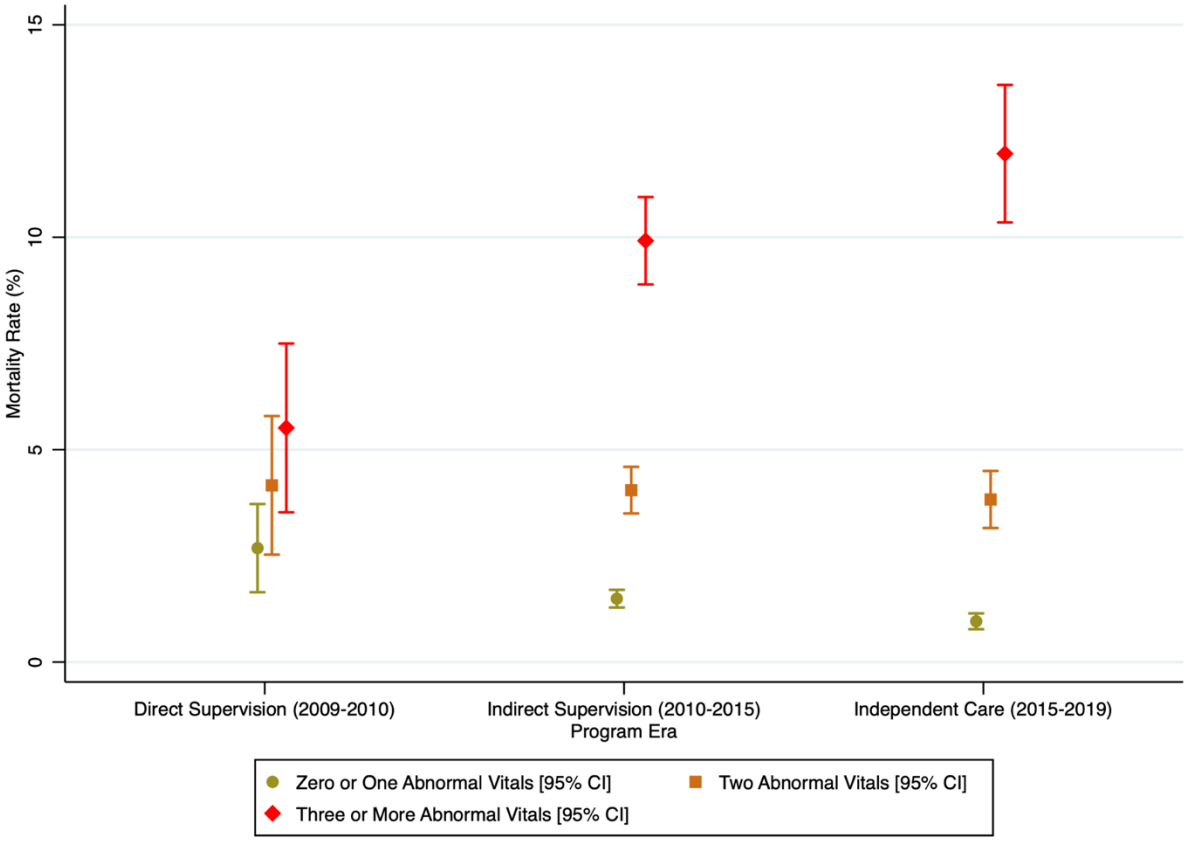

Appendix 1: Mortality by Supervision and Abnormal Vital Signs				
	Direct Era	**Indirect Era**	**Independent Era**	**P-value**
Mortality by number of abnormal vital signs, % [95% CI] (n)				
0 or 1	2.7% [1.6 - 3.7] (25)	1.5% [1.3 - 1.7] (194)	1.0% [0.8 - 1.1] (100)	<0.001
2	4.2% [2.5 - 5.8] (24)	4.1% [3.5 - 4.6] (201)	3.8% [3.2 - 4.5] (120)	0.86
3 or more	5.5% [3.5 - 7.5] (28)	9.9% [8.9 - 10.9] (322)	12% [10.3 -13.4] (185)	<0.001

All p-values calculated with chi-squared

The RECORD statement – checklist of items, extended from the STROBE statement, that should be reported in observational studies using routinely collected health data.

	Item No.	STROBE items	Location in manuscript where items are reported	RECORD items	Location in manuscript where items are reported
Title and abstract					
	1	(a) Indicate the study's design with a commonly used term in the title or the abstract (b) Provide in the abstract an informative and balanced summary of what was done and what was found		RECORD 1.1: The type of data used should be specified in the title or abstract. When possible, the name of the databases used should be included. RECORD 1.2: If applicable, the geographic region and timeframe within which the study took place should be reported in the title or abstract. RECORD 1.3: If linkage between databases was conducted for the study, this should be clearly stated in the title or abstract.	1
Introduction					
Background rationale	2	Explain the scientific background and rationale for the investigation being reported			3
Objectives	3	State specific objectives, including any prespecified hypotheses			5
Methods					
Study Design	4	Present key elements of study design early in the paper			8
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection			6

Participants	6	*(a) Cohort study* - Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study* - Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study* - Give the eligibility criteria, and the sources and methods of selection of participants *(b) Cohort study* - For matched studies, give matching criteria and number of exposed and unexposed *Case-control study* - For matched studies, give matching criteria and the number of controls per case		RECORD 6.1: The methods of study population selection (such as codes or algorithms used to identify subjects) should be listed in detail. If this is not possible, an explanation should be provided. RECORD 6.2: Any validation studies of the codes or algorithms used to select the population should be referenced. If validation was conducted for this study and not published elsewhere, detailed methods and results should be provided. RECORD 6.3: If the study involved linkage of databases, consider use of a flow diagram or other graphical display to demonstrate the data linkage process, including the number of individuals with linked data at each stage.	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable.		RECORD 7.1: A complete list of codes and algorithms used to classify exposures, outcomes, confounders, and effect modifiers should be provided. If these cannot be reported, an explanation should be provided.	7
Data sources/ measurement	8	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group			7

Bias	9	Describe any efforts to address potential sources of bias			7
Study size	10	Explain how the study size was arrived at			7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why			8
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions (c) Explain how missing data were addressed (d) *Cohort study* - If applicable, explain how loss to follow-up was addressed *Case-control study* - If applicable, explain how matching of cases and controls was addressed *Cross-sectional study* - If applicable, describe analytical methods taking account of sampling strategy (e) Describe any sensitivity analyses			8
Data access and cleaning methods		..		RECORD 12.1: Authors should describe the extent to which the investigators had access to the database population used to create the study population.	9

				RECORD 12.2: Authors should provide information on the data cleaning methods used in the study.	
Linkage		..		RECORD 12.3: State whether the study included person-level, institutional-level, or other data linkage across two or more databases. The methods of linkage and methods of linkage quality evaluation should be provided.	n/a
Results					
Participants	13	(a) Report the numbers of individuals at each stage of the study (*e.g.*, numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed) (b) Give reasons for non-participation at each stage. (c) Consider use of a flow diagram		RECORD 13.1: Describe in detail the selection of the persons included in the study (*i.e.,* study population selection) including filtering based on data quality, data availability and linkage. The selection of included persons can be described in the text and/or by means of the study flow diagram.	9
Descriptive data	14	(a) Give characteristics of study participants (*e.g.*, demographic, clinical, social) and information on exposures and potential confounders (b) Indicate the number of participants with missing data for each variable of interest (c) *Cohort study* - summarise follow-up time (*e.g.*, average and total amount)			10
Outcome data	15	*Cohort study* - Report numbers of outcome events or summary measures over time *Case-control study* - Report numbers in each exposure			11

		category, or summary measures of exposure *Cross-sectional study* - Report numbers of outcome events or summary measures			
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence interval). Make clear which confounders were adjusted for and why they were included (b) Report category boundaries when continuous variables were categorized (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period			11
Other analyses	17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses			15
Discussion					
Key results	18	Summarise key results with reference to study objectives			15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias		RECORD 19.1: Discuss the implications of using data that were not created or collected to answer the specific research question(s). Include discussion of misclassification bias, unmeasured confounding, missing data, and changing eligibility over time, as they pertain to the study being reported.	19
Interpretation	20	Give a cautious overall interpretation of results considering objectives,			20

		limitations, multiplicity of analyses, results from similar studies, and other relevant evidence			
Generalisability	21	Discuss the generalisability (external validity) of the study results			19
Other Information					
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based			n/a
Accessibility of protocol, raw data, and programming code		..		RECORD 22.1: Authors should provide information on how to access any supplemental information such as the study protocol, raw data, or programming code.	n/a

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Mortality Outcomes in Task-Sharing for Emergency Care: Impact of Emergency Physician Supervision on Non-Physician Emergency Care in Rural Uganda

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Mortality Outcomes in Task-Sharing for Emergency Care: Impact of Emergency Physician Supervision on Non-Physician Emergency Care in Rural Uganda

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There are no competing interests for any author.

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ABSTRACT

Introduction

Emergency care capacity is limited by physician shortages in low-income countries like Uganda. Delegating tasks to non-physician clinicians — "Task-sharing" — is a proposed solution. This study assesses whether different levels of emergency medicine physician supervision of non-physician clinician care impacts three-day mortality.

Methods

Retrospective analysis of an emergency care training program in rural Uganda included three supervision cohorts of patients receiving care from non-physician clinicians: "Direct Supervision" (2009-2010): emergency medicine physicians directly supervised all care; "Indirect Supervision" (2010-2015): emergency medicine physicians were consulted as needed; "Independent Care" (2015-2019): no emergency medicine physician supervision. Multivariable logistic regression models were developed to assess the independent association between supervision cohorts and three-day mortality. Multiple imputation was used for missing data.

Results

38,033 ED visits met inclusion criteria. Overall mortality decreased significantly across supervision cohorts (3.8% to 3.3% to 2.6%, $p<0.001$), but so too did the rates of patients presenting with ≥3 abnormal vitals (32% to 19% to 13%, $p<0.001$). After controlling for vital sign abnormalities, "Direct" and "Indirect" supervision were significantly independently associated with reduced OR for mortality ("Direct": 0.57 [0.37-0.90], "Indirect": 0.71 [0.55 - 0.92]) when compared to "Independent Care". Sensitivity analysis showed that this mortality benefit was significant for the minority of patients (17.2%) with ≥3 abnormal vitals ("Direct": 0.44 [0.22-0.85], "Indirect": 0.60 [0.41 -0.88]), but not for the majority (82.8%) with 2 or fewer abnormal vitals ("Direct": 0.81 [0.44-1.49], "Indirect": 0.82 [0.58 -1.16]).

Conclusion

Emergency medicine physician supervision of emergency care non-physician clinicians is independently associated with reduced overall mortality. This benefit appears restricted to the highest risk patients based on abnormal vitals. With over 80% of patients having equivalent mortality outcomes with independent non-physician clinician emergency care, a synergistic model providing variable levels of emergency medicine physician supervision or care based on patient acuity could safely address staffing shortages.

SUMMARY BOX

What is already known?

- Physician shortages and lack of specialty training limit implementation of emergency care and associated reductions in mortality in low- and middle-income countries such as Uganda.
- Task-sharing, often to non-physician clinicians, is proposed as a solution however data to support safe, effective training and physician supervision protocols is limited.

What are the new findings?

- The highest risk approximately 15% of emergency care patients – based on abnormal vital signs - have a 50% reduction in mortality when emergency medicine physicians supervise non-physician clinician care.

- For most emergency care patients (the lowest risk approximately 85%) independent emergency care by non-physician clinicians provides similar morality outcomes to care when supervised by an emergency medicine physician.

What do the new findings imply?

- Training of both emergency care physicians and non-physician clinicians is essential, as physicians provide improved mortality outcomes, especially for the critically ill, and non-physician clinicians will help address lack of trained and available emergency care providers in a timely, cost-effective manner.
- Physician supervision of all emergency care is the ultimate goal, however non-physician clinicians can be trained to provide comparable morality outcomes for the vast majority of patients when practicing independently.
- Triage protocols are needed to identify high-risk emergency care patients, such as those with 3 or more abnormal vital signs, for early involvement of an emergency physician either directly, or through supervision of a non-physician clinician.

INTRODUCTION

Global recognition of the need to develop emergency care is growing. [1,2] In low- and middle-income countries (LMIC), physician shortages make the provision of medical care and in particular emergency care problematic, with the greatest challenge centered in Sub-Saharan Africa (SSA). [3–5] Emergency care needs remain largely unmet throughout many LMICs, including Uganda. [5–8] Based on the estimate that 57% of deaths occurring in low-income countries are from conditions treatable with emergency care, approximately 160,000 Ugandans' lives could have been saved by provision of emergency care in 2019. [9,10] Emergency care in Uganda is largely limited by physician shortages, as there are 1.68 physicians per 10,000 people, amongst the lowest rates worldwide. [11]. Uganda has placed a priority on developing emergency care over the next five years, estimating that 454 specialist emergency care physicians will be required by 2025. [12] Emergency care specialty training in Uganda began in 2017 and currently certifies between five and 10 Ugandan emergency medicine specialists per year.[13] This leaves an enormous training gap with between 45 and 90 years of training needed to produce emergency medicine specialists to meet the projected five-year staffing demands.

One solution to address physician shortage that has been widely advocated and implemented in SSA is "task-sharing," or delegating tasks to cadres of new or existing providers, often non-physician clinicians, who do not have the broad-ranging, expensive and lengthy training of physicians. [14–20] The World Health Organization advocates for non-physician clinicians that are "adequately trained, supported and supervised". [18,20] Though non-physician clinicians are currently providing surgical specialty, obstetric, and HIV care throughout SSA [21–27], there has been limited application of non-physician clinician cadres to offset emergency care provider shortages. [19,28,29] High-income countries have compensated for regionally inadequate physician numbers and uneven distribution of emergency physicians by adopting physician supervised non-physician clinicians in larger emergency units and in some cases non-physician clinician practice with remote physician supervision in smaller rural hospitals. [30–33] Data and protocols to guide implementation of emergency care non-physician clinician training and practice in LMICs, where emergency medicine is largely newly developing, and emergency medicine physicians are typically not available, is highly limited.

Few studies exist addressing training of non-physician clinicians for roles in the African acute care settings outside of trainings focused on specific obstetric, surgical or anesthesia procedures [34–37], while others find that emergency and acute care training is lacking in non-physician clinician education in many SSA countries including Uganda. [34,38] There are documentation a few short-courses designed to teach non-physician clinicians emergency care skills in SSA. [39–42] While our research group has published on an emergency care non-physician clinician training program and its associated outcomes, we are not aware of any additional studies documenting a comprehensive emergency care non-physician clinicians training program in a LMIC. [29,43–48] Consistent with this limited evidence base, no standards exist describing if, when or how to transition to reduced supervision or independent non-physician clinician care following initial training. This represents a major limitation in the ability to implement non-physician clinician training, supervision and uptake into health systems in a safe, effective and evidence-based manner.

While health systems are evolving in Uganda over the last decade so too is the health of the general population. Uganda's national crude death rates decreased by 63% across all age groups (10.2/1000 in 2009 to 6.4/1000 persons in 2019) during the study period. [49] Concurrently, life expectancy increased by 6.8 years and rates of malaria and HIV infection decreased. [49]

Emergency care has been delivered by non-physician clinicians in Uganda since 2009 in a training program that has transitioned from directly supervised to independent non-physician clinician care. The objective of this study was to test the hypothesis that increasing levels of emergency medicine physician supervision for three cohorts of non-physician clinicians were independently associated with reduced three-day patient mortality. Logistic regression modelling was used to control for the changing baseline health of the Ugandan population. Sensitivity analysis was performed to account for missing data and to attempt to define which populations of patients had mortality outcomes impacted by physician supervision.

METHODS

Description of Study Site

All data comes from the emergency unit at Karoli Lwanga Hospital, a rural district hospital located in the town of Nyakibale in the Rukungiri District of southwest Uganda. The hospital has a six-bed emergency unit that opened in 2008 and treats 300 to 700 patients per month arriving between 8:00 am and midnight every day of the year. Since 2009, the emergency unit has been staffed by non-physician clinicians who received training from emergency medicine physicians working with Global Emergency Care. The non-physician clinicians are nurses who have completed a two-year advanced training course in emergency care described in detail elsewhere by Hammerstedt et al [29]. While the course is currently administered in conjunction with Mbarara University of Science and Technology, the non-physician clinicians in this cohort study were trained as part of the pilot program that began through a collaboration between GEC and Karoli Lwanga Hospital. Global Emergency Care (GEC), a US-based 501(c)[3] non-governmental organization, has run a two-year emergency care specialty non-physician clinician training program since 2009, and currently does so in collaboration with Mbarara University of Science and Technology (MUST).

Supervision of the non-physician clinicians changed over time generating three cohorts: "Direct Supervision", "Indirect Supervision" and "Independent Care". "Direct Supervision" occurred from November 2009 - April 2010 when a single US-trained emergency medicine

physician practicing with a Ugandan license was on site every day and directly supervised non-physician clinician care and supplemented with clinical care in a model similar to US residency training. “Indirect Supervision” occurred from July 2010 - November 2015. During this period a volunteer US-trained emergency medicine physician was on site for approximately 85% of the weeks; however, they were present in a teaching role only and provided no direct patient care. They were available for consultation on an ad hoc basis and consultation was based on non-physician clinician discretion. “Independent Care” occurred from December 2015 - December 2019, and non-physician clinicians provided clinical care without any onsite emergency medicine physician. During the entire study period, no Ugandan physicians were assigned to the emergency unit. Hospital physicians were available in a similar manner throughout the study period for consultation for patients who required surgery, did not respond to initial treatments, or in whom there was considerable diagnostic uncertainty. Throughout the study period, non-physician clinicians admitted patients to the same hospital medical and surgical wards, which were staffed by Ugandan physicians with standard levels of training and no connection to GEC. Resource availability was constant over the study period and with resource utilization by clinicians in this emergency unit described in detail elsewhere. [43]

Patient and Public Involvement

The non-physician clinician training program was originally developed in response to several years of clinical emergency medicine experience and ongoing healthcare staffing shortages in Uganda. The positive response of patients, staff and administrators at Karoli Lwanga Hospital to the training program and their interest in improving patient care led to ongoing research and program evaluation. Patients and the public were not involved in the design of the study; however, outcome measures are explicitly patient-oriented. Results have been and will continue to be disseminated through open access publications to allow local clinicians, administrators, policymakers and researchers to benefit.

Data Collection

GEC maintained a group of trained research associates who prospectively collected quality assurance data on all Karoli Lwanga Hospital emergency unit patient visits. Collected data included demographics, vital signs, laboratory and radiology testing, disposition, as well as three-day follow-up vital status (mortality) for all admitted and discharged patients. On the third day following initial evaluation in the emergency unit, patients admitted to the hospital were visited in person, and patients discharged from the emergency unit or ward were contacted via phone. This follow-up protocol included seven consecutive days of calling all patients on the phone (if they had a phone) before considering them lost to follow-up and is described in detail elsewhere. [29] Ethics approval for the quality assurance database and waiver of consent was obtained through the Institutional Review Board at Mbarara University of Science and Technology (No. 11/08-12). Trained research assistants entered data using Microsoft Excel from 1 January 2010 – 23 March 2012, and Microsoft Access from 24 March 2012 – 31 December 2019.

Data Analysis

A cohort study was done using retrospective analysis of prospectively collected data abstracted from the Karoli Lwanga Hospital emergency unit quality assurance database, including all consecutive patients presenting to the emergency unit from November 2009 until December 2019. All patients missing age, gender, disposition and three-day follow up were excluded from analysis. Patients who were dead on arrival (lacked vital signs with no resuscitation or interventions attempted) and patients who were transferred or left against

medical advice did not receive follow-up by protocol and thus were also excluded from analysis. All other patients of all ages and dispositions were included. Age, gender, vital signs, malaria testing, HIV status, gestalt assessment of clinical condition, and year of service were recorded for all patients. Data was abstracted, cleaned, and analyzed by a single researcher (BR) using Stata 16.1 (StataCorp, College Station, TX). Missing data was imputed using multiple imputation by chained equations in Stata. Ten datasets were imputed and combined, with disposition and age groups used as auxiliary variables to predict missingness based on the results described below. Because only two months of data existed for 2009, and no data was collected for three months in 2010 while the program transitioned from "Direct" to "Indirect", the years 2009 and 2010 were both coded as 2010 for the continuous "Year" variable included in that model. Twelve variables were included for the final model meeting the minimal criterion of approximately ten events per variable (n=1,169 events overall).[50] All variables with a univariate p-value less than 0.15 were included in the final model. Area Under Receiver Operating Characteristics Curve (AUROC), Hosmer-Lemeshow Goodness of Fit, and Brier score were all calculated for logistic regression models. No a priori power or sample size calculations were performed as all available records were included in analysis. Continuous variables were tested for significance using one-way ANOVA and proportions were compared using chi-squared.

RESULTS

Overall, 49,315 patient visits occurred from 2009 - 2019, and 38,033 (77.1%) met criteria for inclusion for analysis. Inclusion and exclusion criteria are shown in Figure 1 below.

Figure 1: Patient Flow Diagram

Patient characteristics stratified by cohorts of patients receiving non-physician emergency care with different levels of emergency medicine physician supervision (as described in Methods above) are shown in Table 1 below.

Table 1: Patient Characteristics

Characteristic	Direct Supervision Cohort (n=1,875)	Indirect Supervision Cohort (n=21,052)	Independent Care Cohort(n=15,106)	P-value
Age, mean (SD)	25.9 (23.5)	28.8 (24.1)	32.9 (24.9)	< 0.001*
Age Group				
Under 5, % (n)	26.7% (501)	21.2% (4454)	14.5% (2196)	< 0.001
5-17 y.o., % (n)	15.2% (285)	15.8% (3325)	14.7% (2219)	
18-64 y.o., % (n)	48.3% (910)	51.7% (10890)	56.5% (8538)	
> = 65 y.o., % (n)	9.6% (179)	11.3% (2383)	14.3% (2153)	
HIV-positive , % (n)	1.9% (35)	5.6% (1182)	6.9% (1045)	< 0.001
Malaria parasites on blood smear, % (n)	24.5% (460)	18.5% (3903)	5.6% (848)	< 0.001
Gender - Female, % (n)	47.9% (898)	46.2% (9719)	46.6% (7046)	0.29
Complete Vital Signs				
Under 5 Years Old, %(n)	36.1% (190)	8.5% (401)	8.5% (205)	<0.001
5-12 Years Old, %(n)	79.6% (86)	57.8% (758)	49.8% (444)	<0.001
13 Years and Older, %(n)	88.1% (1092)	87.8% (13163)	90.4% (10672)	<0.001
Vital Sign Abnormalities				
Blood Pressure				
Normal, % (n)	58.2% (1,092)	63.5% (13,368)	72.6% (10,959)	<0.001
Hypotensive, % (n)	21.4%(401)	12.0% (2,528)	7.9% (1,194)	
Missing, % (n)	20.4% (382)	24.5% (5,156)	19.6% (2,953)	
Respiratory Rate				

	Normal, % (n)	38.9% (730)	53.5% (11,266)	66.2% (10,000)	
	Tachypnea, % (n)	52.8% (990)	43.3% (9,121)	27.7% (4,181)	<0.001
	Missing, % (n)	8.27% (155)	3.16%(665)	6.12%(925)	
Oxygen Saturation					
	Normal, % (n)	83.7% (1,569)	80.6% (16,965)	84.2% (12,722)	
	Hypoxic , % (n)	13.2% (248)	12.0% (2,533)	12.7% (1,915)	<0.001
	Missing, % (n)	3.1% (58)	7.4% (1,554)	3.1%(469)	
Heart Rate					
	Normal, % (n)	48.9%(971)	62.5% (13,161)	64.2% (9,703)	
	Tachycardic, % (n)	49.0%. (918)	36.6% (7,695)	33.8% (5,112)	<0.001
	Missing, % (n)	2.1%(40)	0.9%(196)	1.93%(291)	
Temperature					
	Normal, % (n)	38.4%. (719)	55.3% (11,646)	54.6% (8,250)	
	Hypothermic , % (n)	35.7%. (670)	27.5% (5,779)	29.4% (4,444)	<0.001
	Febrile, % (n)	22.4%(420)	15.7% (3,304)	13.6% (2,049)	
	Missing, % (n)	3.5% (66)	1.5% (323)	2.4% (363)	

* ANOVA used for significance test; all others use chi-squared

There were significant differences in every characteristic across the cohorts except for gender. As the study progressed there were fewer pediatric patients, more adult and elderly patients, fewer patients with malaria, more patients with HIV, and more patients with abnormal vitals. Missingness was relatively low for all vital signs (0.9% - 8.3%) except blood pressure which had a much higher rate of missingness (19.6% - 24.5%). That missingness was almost entirely restricted to the pediatric population (0-5 Years Old: 88.6% [n=6,803] missing blood pressure, 6-12 Years Old: 39.9% (n=922] missing blood pressure, 13 Years and Older: 2.7% [n=766] missing blood pressure).

The three-day mortality for the program overall (2009-2019) was 3.1% (n=1,169 deaths), and mortality decreased significantly as the program transitioned from "Direct Supervision" to "Indirect Supervision" to "Independent Care" (3.8% [n=72], 3.3% [n=698], 2.6% [n=399] respectively, $p<0.001$). Simultaneously, across those time periods patients presented with significantly fewer abnormal vital signs (Figure 2). Over the entire program, mortality increased monotonically with each additional abnormal vital sign (Zero Abnormal = 0.7% [n=66], One Abnormal=1.7% [n=222], Two Abnormal=3.4% [n=321], Three or more=8.6% [n=561], $p<0.001$).

Figure 2: Mortality and vital sign abnormalities across supervision cohorts

Given this changing baseline in patient mortality and prevalence of vital sign abnormalities, a logistic regression model was developed to determine whether "Direct Supervision" and/or "Indirect Supervision" was independently associated with increased or decreased mortality as compared to "Independent Care".

The development of this model incorporated the finding that there was a strong association with missing vital signs and mortality with a monotonic increase in mortality for each missing vital sign (Zero Missing: 2.7% [n=746], One Missing: 3.3% [n=319], Two Missing: 7.0% [n=66], Three or more Missing:7.5% [n=38], $p<0.001$). The highest mortality population ("Expired in ED" with 100% mortality) had over half the patients (55.4%, n=103) missing one or more vitals. Therefore, when we attempted complete case analysis for logistic regression, only 70.7% of patients (n=26,869) were included in the model (including only 9.7% of children under five years old) and only 63.4% (n=741) of deaths were included. Therefore, complete case analysis was rejected in favor of multiple imputation (complete case analysis results are available as Appendix 1 and Appendix 2).

Using multiple imputation by chained equations over ten datasets (as described in Methods), we were able to produce a logistic regression model that included all 38,033 patients (Table 2).

Table 2: Logistic Regression Model of Mortality Comparing Supervision Cohorts

	Multiple Imputation (n=38,033)		
	OR	95% CI	p-Value
Age Group			
Under 5	1.29	0.77 - 1.14	0.008
5-12 y.o.	0.49	0.55 - 0.90	<0.001
18-64 y.o.	REF		
>=65 y.o.	1.63	1.37 - 1.93	<0.001
HIV			
Negative	REF		
Positive	1.84	1.51 - 2.25	<0.001
Malaria			
Negative	REF		
Positive	0.93	0.78 - 1.12	0.708
Gender			
M	REF		
F	0.71	0.62 - 0.80	<0.001
Oxygen Saturation			
Normal	REF		
Hypoxic	2.95	2.55 - 3.41	<0.001
Respiratory Rate			
Normal	REF		

Tachypnea	1.82	1.58	-	2.11	<0.001
Heart Rate					
Normal	REF				
Tachycardic	1.18	1.03	-	1.36	0.02
Blood Pressure					
Normotensive	REF				
Hypotensive	1.65	1.39		1.96	0.027
Temperature					
Normal					
Hypothermic	2.09	1.81	-	2.42	<0.001
Febrile	0.80	0.66	-	0.98	0.034
Year	0.90	0.86	-	0.95	<0.001
Clinical Impression					
"Not Sick"					
"Sick"	4.81	3.91	-	5.90	<0.001
"Toxic"	35.6	27.8	-	45.5	<0.001
Supervision					
Independent	REF				
Direct	0.57	0.37	-	0.90	0.015
Indirect	0.71	0.55	-	0.92	0.01

This model had excellent discrimination (AUROC : 0.87 [0.85 – 0.88]), goodness of fit (Hosmer-Lemeshow: 0.991) and accuracy (Brier score: 0.256). This model found that both "Direct" and "Indirect" supervision were significantly independently associated with reduced OR for mortality ("Direct": 0.57 [0.37-0.90], "Indirect": 0.71 [0.55 -0.92]) when compared to "Independent Care". As a sensitivity analysis, patients with and without three or more abnormal vital signs were analyzed separately (Figure 3).

Figure 3: Odds Ratios for Mortality comparing Direct Supervision and Indirect Supervision to Independent Care

For the minority of patients with three or more abnormal vital signs (17.2%, n=6,451), both "Direct" and "Indirect" supervision were significantly independently associated with reduced OR for mortality ("Direct": 0.44 [0.22-0.85], "Indirect": 0.60 [0.41 -0.88]). However, for the majority of patients who had two or fewer abnormal vital signs (82.8%, n=31,492) there was no significant difference in OR for mortality ("Direct": 0.81 [0.44-1.49], "Indirect": 0.82 [0.58 -1.16]).

DISCUSSION

This study of a non-physician clinician emergency care training program in rural Uganda demonstrates that direct and indirect supervision by emergency medicine physicians reduced overall mortality as compared to independent non-physician clinician emergency care. Sensitivity analysis showed this benefit was restricted to the most severely ill subset of patients – as defined by abnormal vitals – with independent non-physician clinician care having similar outcomes to physician-supervised care for the vast majority of patients. These findings are consistent with a prior study by our author group showing the mortality benefit for direct emergency medicine physician supervision was restricted to the most severely ill subset of children under 5 years of age [46]. We are not aware of any other studies addressing mortality rates of patients cared for by emergency care specialty trained non-physician clinicians in similar LMIC settings. This finding has potentially profound implications for policy to maximize workforce potential in the rapidly developing field of emergency care in Uganda and in similar settings.

One of the fundamental challenges of our analysis was the rapidly changing background of the health system in Uganda during the study period (2009-2019). Many of the most profound shifts seen in our study likely reflect the overall changes in Ugandan health care. As shown in Figure 2, overall mortality significantly ($p<0.001$) decreased by almost 70% during the study period. While impressive, this finding is consistent with the 63% reduction in national crude death rate during the study period [49]. Similarly, we saw many demographic shifts in our population over time (Table 1) including fewer emergencies in children under 5, more elderly patients and reduced rates of malaria. Again, these are consistent with Ugandan national trends over that time period.[49]

Logistic regression models were developed control for confounding variables. As mentioned in Results, high rates of missing data for the highest mortality patients and children under five years old made complete-case analysis a poor fit for our data set. Multiple imputation was eventually selected as the optimal method for handling missing data.[51,52] Single

(deterministic) imputation models were developed but ultimately discarded based on poor performance. The multiple imputation model had excellent characteristics (discrimination, goodness of fit, and accuracy) and showed that both "Direct Supervision" and "Indirect Supervision" reduced program mortality overall as compared to "Independent Care". This is an expected finding, as no argument exists in this manuscript or elsewhere suggesting complete equality between physician and non-physician clinician training, practice or outcomes. Rather, this finding clearly highlights the importance of the scaling-up of the ongoing emergency medicine physician training efforts in Uganda to reduce mortality in emergencies nationwide.

While emergency medicine physician care for all emergency patients is ideal, the current rate of emergency medicine specialist training, health system funding, and high demand for emergency medicine specialist physicians at training institutions and in administrative roles, means that the ideal of emergency medicine specialist clinical care in emergency units throughout Uganda may be decades away from being realized. Therefore, optimizing the role of non-physician clinicians can help address the current gap between emergency care patients and providers.

Sensitivity analysis was performed to attempt to identify which subset of patients might benefit most from physician supervision. With prior studies showing the benefit of direct physician supervision of non-physicians was limited to severely ill pediatric patients, our sensitivity analysis involved stratifying by vital signs.[46] We found that minority of patients with three or more abnormal vital signs (16.7%, n=6,541) had significantly reduced OR of mortality, and that reduction was enough to create a significant mortality impact for those supervision cohorts overall. However, when the majority of patients with two or fewer abnormal vital signs were looked at separately there was no significant reduction in mortality when comparing either "Direct Supervision" or "Indirect Supervision" to "Independent Care". We believe this finding could be used at triage to immediately identify patients most likely to receive benefit from emergency medicine physician supervision in clinical situations where that resource is too limited to be provided for all patients.

We strongly support the ongoing development of emergency medicine specialty training for physicians in Uganda to help achieve the ultimate goal of providing emergency medicine physician clinical care for all patients. However, current emergency care staffing shortages in Uganda and elsewhere in Sub-Saharan Africa are likely to persist for decades to come. Augmenting the physician workforce with emergency care specialty-trained non-physician clinicians — who can be trained more rapidly, at a lower cost, and are more likely to work in rural areas — is a clear path forward to addressing the immediate emergency care needs faced by millions of Ugandans today.[3,20,38,53] Our analysis shows that a synergy between these groups is possible: non-physician clinicians can safely deliver independent care for the majority of less severely ill patients without causing excess mortality, while emergency medicine physicians can provide or supervise non-physician clinician care to reduce mortality for the most severely ill subset of patients.

Limitations

This is a single center, retrospective study of an emergency unit database. Mortality follow-up was limited to three days. While one week and one month mortality is undoubtedly important, three-day follow-up was chosen both to minimize loss to follow-up in a setting where most patients do not have consistent ability to receive phone calls and because follow-up after three days was thought to be less reflective of outcomes related to acute care provided in the emergency unit. Inpatient mortality was affected not just by emergency unit care but also by

hospital ward care. However, this care was provided similarly throughout the study, making it unlikely to bias outcomes in comparisons between cohorts. Multiple imputation is a widely accepted method for dealing with missing data, but even with auxiliary variables used to improve the likelihood of meeting the missing at random assumption, any approach to missing data is imperfect with multiple imputation being no exception. Lastly, there was a high loss to follow-up in discharged patients over the duration of the study (47.7%, n=8,110). Most of this loss to follow was due to lack of phones for the discharged patients (Had no phone: 82.3%, n=6,592; Invalid number: 6.9%, n=553) with only 10.7% (n=856) being loss to follow up for other reasons. However, with a mortality rate of 0.07% (n=6 deaths in 8,906 discharges) in discharged patients with complete follow-up, it is highly unlikely that the 8,110 discharged patients lost to follow-up represent a significant number of fatal cases excluded from our analysis. The 6.3% loss to follow-up rate for admitted and direct to theatre patients was otherwise considered adequate given the challenges of emergency unit data collection in Sub-Saharan Africa.

CONCLUSIONS

This manuscript shows that task-sharing of emergency care specialty-trained non-physician clinicians to address emergency care staffing shortages is both efficient and safe for the vast majority of patient encounters. As Uganda strives to reach the goal of consistent emergency medicine physician coverage of emergency units, operationalizing a hybrid model with emergency medicine physician supervision of otherwise independent non-physician clinician care for the sickest emergency care patients has the potential to save lives. Based on the robust evidence base we report above, the authors' recommendations are as follows:

1. Scale up emergency medicine physician development and training: The highest risk approximately 15% of patients had nearly a 50% reduction in mortality with physician involvement, and direct supervision significantly reduced overall mortality.
2. Increase capacity for emergency care NCP training: emergency care non-physician clinicians provided independent care comparable to care given with emergency medicine physician supervision for approximately 85% of patients over the study period.
3. Create triage protocols for early identification of the highest risk patients: in our analysis patients with three or more abnormal vital signs were most likely to derive benefit from emergency medicine physician clinical care or supervision of non-physician clinician care.
4. Create clear protocols and systems to provide emergency care non-physician clinicians with direct supervision in person or via phone/telehealth consultation by emergency medicine physician for patients at high-risk of mortality.

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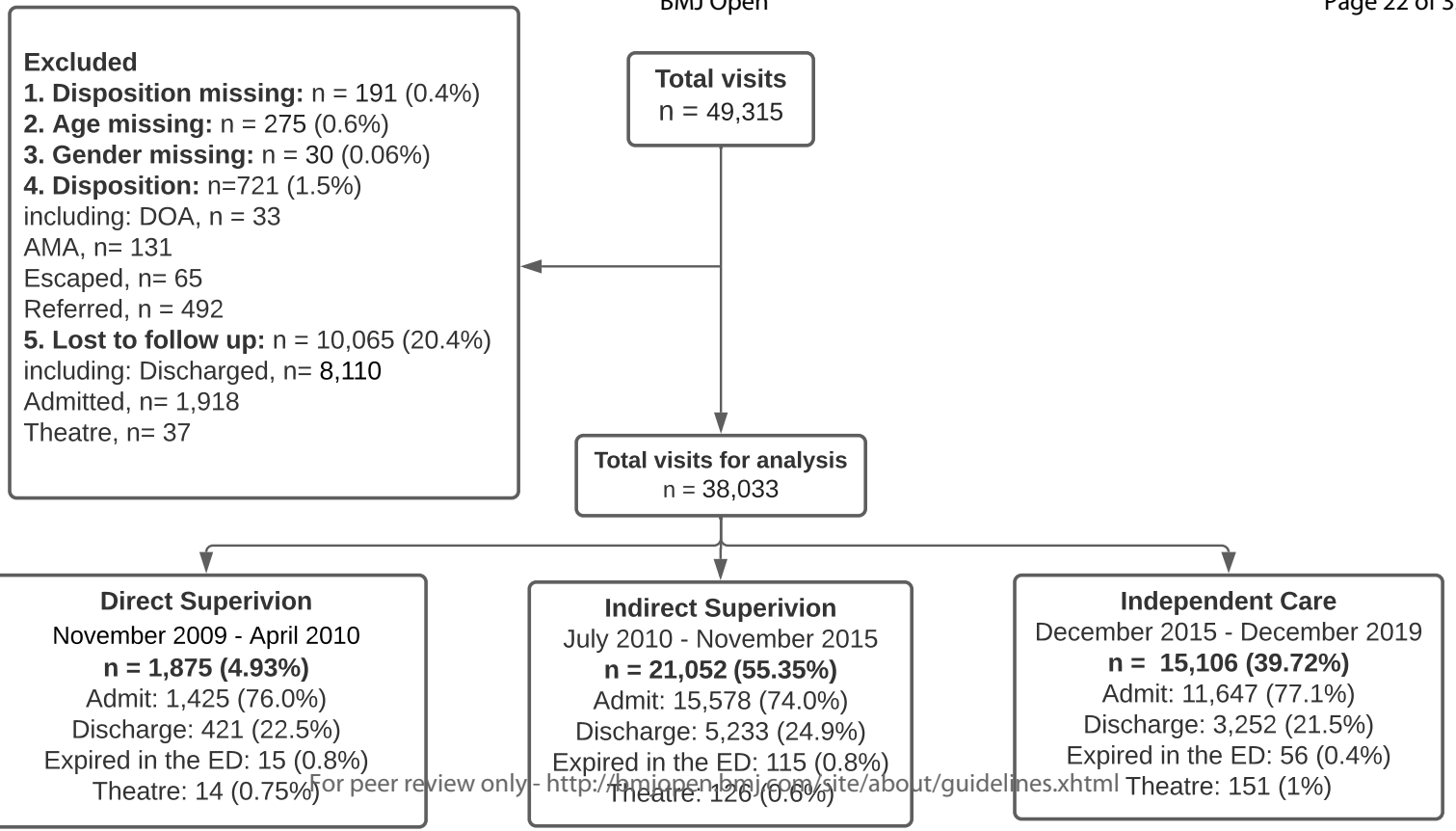

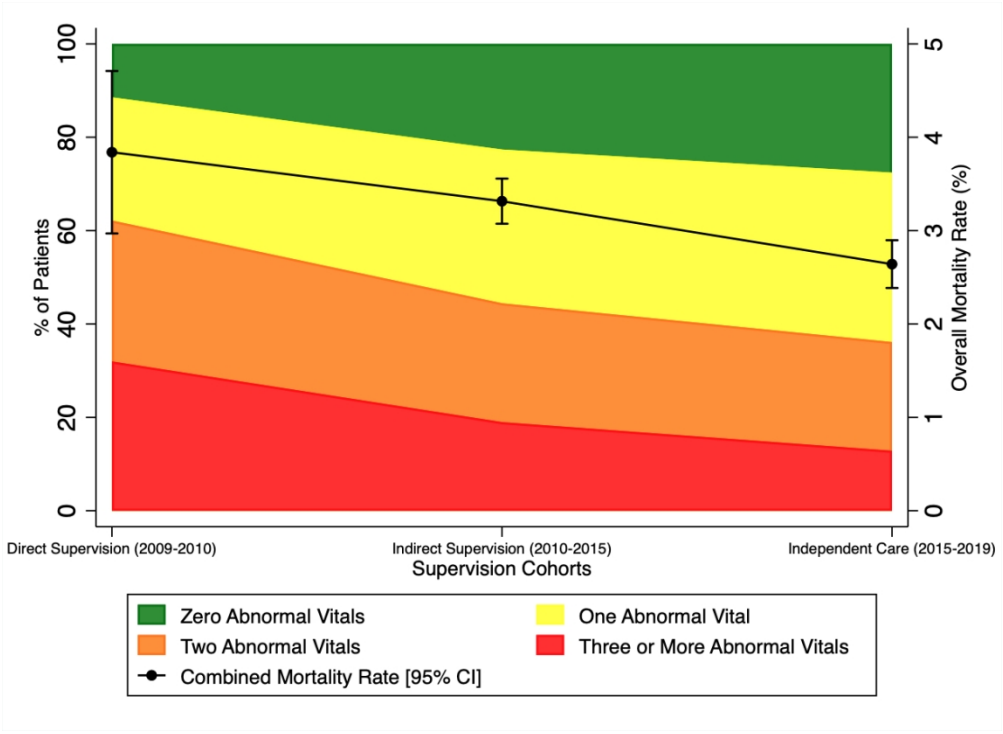

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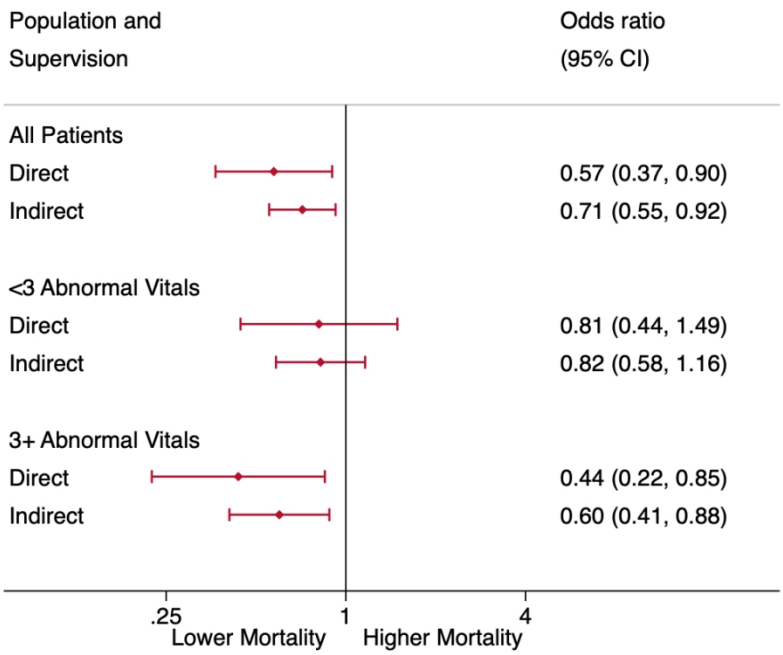

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APPENDIX 1: **Odds Ratios for Mortality comparing Direct Supervision and Indirect Supervision to Independent Care (Complete Case Analysis)**

	Complete Case Analysis (n=26,869)				
	OR	95% CI			p-Value
Age Group					
Under 5	0.60	0.33	-	1.10	0.1
5-12 y.o.	0.52	0.37	-	0.72	<0.001
18-64 y.o.	REF				
>=65 y.o.	1.59	1.31	-	1.91	<0.001
HIV					
Negative	REF				
Positive	1.75	1.40	-	2.19	<0.001
Malaria					
Negative	REF				
Positive	1.08	0.85	-	1.36	0.546
Gender					
M	REF				
F	0.56	0.47	-	0.66	<0.001
Oxygen Saturation					
Normal	REF				
Hypoxic	3.11	2.62	-	3.69	<0.001
Respiratory Rate					
Normal	REF				
Tachypnea	1.92	1.61	-	2.30	<0.001
Heart Rate					
Normal	REF				
Tachycardic	1.30	1.10	-	1.54	0.002
Blood Pressure					
Normotensive	REF				
Hypotensive	1.89	1.58		2.25	<0.001

Temperature					
Normal	REF				
Hypothermic	1.96	1.65	-	2.33	<0.001
Febrile	0.82	0.64	-	1.05	0.119
Year	0.95	0.90	-	1.01	0.101
Clinical Impression					
"Not Sick"	REF				
"Sick"	4.20	3.31	-	5.32	<0.001
"Toxic"	23.2	17.1	-	31.5	<0.001
Supervision					
Independent	REF				
Direct	0.79	0.45	-	1.40	0.42
Indirect	0.77	0.56	-	1.05	0.097

Appendix 2: Odds Ratios for Mortality comparing Direct Supervision and Indirect Supervision to Independent Care

	OR [95% CI]
3+ Abnormal Vitals	
Direct Supervision	**0.61 [0.43 - 0.85]**
Indirect Supervision	0.88 [0.74 - 1.04]
2 Abnormal Vitals	
Direct Supervision	1.63 [0.99 - 2.67]
Indirect Supervision	1.33 [1.02 - 1.73]
1 Abnormal Vital	
Direct Supervision	1.35 [0.61 - 2.98]
Indirect Supervision	**1.44 [1.04 - 2.00]**
0 Abnormal Vitals	
Direct Supervision	2.73 [0.80 - 9.26]
Indirect Supervision	1.17 [0.66 - 2.10]

Bold indicates statistically significant

The RECORD statement – checklist of items, extended from the STROBE statement, that should be reported in observational studies using routinely collected health data.

	Item No.	STROBE items	Location in manuscript where items are reported	RECORD items	Location in manuscript where items are reported
Title and abstract					
	1	(a) Indicate the study's design with a commonly used term in the title or the abstract (b) Provide in the abstract an informative and balanced summary of what was done and what was found		RECORD 1.1: The type of data used should be specified in the title or abstract. When possible, the name of the databases used should be included. RECORD 1.2: If applicable, the geographic region and timeframe within which the study took place should be reported in the title or abstract. RECORD 1.3: If linkage between databases was conducted for the study, this should be clearly stated in the title or abstract.	1
Introduction					
Background rationale	2	Explain the scientific background and rationale for the investigation being reported			3
Objectives	3	State specific objectives, including any prespecified hypotheses			5
Methods					
Study Design	4	Present key elements of study design early in the paper			8
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection			6

Participants	6	*(a) Cohort study* - Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study* - Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study* - Give the eligibility criteria, and the sources and methods of selection of participants *(b) Cohort study* - For matched studies, give matching criteria and number of exposed and unexposed *Case-control study* - For matched studies, give matching criteria and the number of controls per case		RECORD 6.1: The methods of study population selection (such as codes or algorithms used to identify subjects) should be listed in detail. If this is not possible, an explanation should be provided. RECORD 6.2: Any validation studies of the codes or algorithms used to select the population should be referenced. If validation was conducted for this study and not published elsewhere, detailed methods and results should be provided. RECORD 6.3: If the study involved linkage of databases, consider use of a flow diagram or other graphical display to demonstrate the data linkage process, including the number of individuals with linked data at each stage.	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable.		RECORD 7.1: A complete list of codes and algorithms used to classify exposures, outcomes, confounders, and effect modifiers should be provided. If these cannot be reported, an explanation should be provided.	7
Data sources/ measurement	8	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group			7

Bias	9	Describe any efforts to address potential sources of bias			7
Study size	10	Explain how the study size was arrived at			7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why			8
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions (c) Explain how missing data were addressed (d) *Cohort study* - If applicable, explain how loss to follow-up was addressed *Case-control study* - If applicable, explain how matching of cases and controls was addressed *Cross-sectional study* - If applicable, describe analytical methods taking account of sampling strategy (e) Describe any sensitivity analyses			8
Data access and cleaning methods		..		RECORD 12.1: Authors should describe the extent to which the investigators had access to the database population used to create the study population.	9

				RECORD 12.2: Authors should provide information on the data cleaning methods used in the study.	
Linkage		..		RECORD 12.3: State whether the study included person-level, institutional-level, or other data linkage across two or more databases. The methods of linkage and methods of linkage quality evaluation should be provided.	n/a
Results					
Participants	13	(a) Report the numbers of individuals at each stage of the study (*e.g.*, numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed) (b) Give reasons for non-participation at each stage. (c) Consider use of a flow diagram		RECORD 13.1: Describe in detail the selection of the persons included in the study (*i.e.,* study population selection) including filtering based on data quality, data availability and linkage. The selection of included persons can be described in the text and/or by means of the study flow diagram.	9
Descriptive data	14	(a) Give characteristics of study participants (*e.g.*, demographic, clinical, social) and information on exposures and potential confounders (b) Indicate the number of participants with missing data for each variable of interest (c) *Cohort study* - summarise follow-up time (*e.g.*, average and total amount)			10
Outcome data	15	*Cohort study* - Report numbers of outcome events or summary measures over time *Case-control study* - Report numbers in each exposure			11

		category, or summary measures of exposure *Cross-sectional study* - Report numbers of outcome events or summary measures			
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence interval). Make clear which confounders were adjusted for and why they were included (b) Report category boundaries when continuous variables were categorized (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period			11
Other analyses	17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses			15
Discussion					
Key results	18	Summarise key results with reference to study objectives			15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias		RECORD 19.1: Discuss the implications of using data that were not created or collected to answer the specific research question(s). Include discussion of misclassification bias, unmeasured confounding, missing data, and changing eligibility over time, as they pertain to the study being reported.	19
Interpretation	20	Give a cautious overall interpretation of results considering objectives,			20

		limitations, multiplicity of analyses, results from similar studies, and other relevant evidence			
Generalisability	21	Discuss the generalisability (external validity) of the study results			19
Other Information					
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based			n/a
Accessibility of protocol, raw data, and programming code		..		RECORD 22.1: Authors should provide information on how to access any supplemental information such as the study protocol, raw data, or programming code.	n/a

*Reference: Benchimol EI, Smeeth L, Guttmann A, Harron K, Moher D, Petersen I, Sørensen HT, von Elm E, Langan SM, the RECORD Working Committee. The REporting of studies Conducted using Observational Routinely-collected health Data (RECORD) Statement. *PLoS Medicine* 2015; in press.

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Emergency medicine physician supervision and morality among patients receiving care from non-physician clinicians in a task-sharing model of emergency care in rural Uganda: a retrospective analysis of a single-centre training programme

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Emergency medicine physician supervision and morality among patients receiving care from non-physician clinicians in a task-sharing model of emergency care in rural Uganda: a retrospective analysis of a single-centre training programme

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ABSTRACT

Objectives: To assess the association between emergency medicine physician supervision and three-day mortality for patients receiving care from non-physician clinicians in a task-sharing model of emergency care in rural Uganda.

Design: Retrospective cohort analysis with multivariable logistic regression.

Setting: Single rural Ugandan emergency unit.

Participants: All patients presenting for care from 2009-2019.

Interventions: Three cohorts of patients receiving care from non-physician clinicians had three different levels of physician supervision: "Direct Supervision" (2009-2010) emergency medicine physicians directly supervised all care; "Indirect Supervision" (2010-2015) emergency medicine physicians were consulted as needed; "Independent Care" (2015-2019) no emergency medicine physician supervision.

Primary outcome measure: Three-day mortality.

Results: 38,033 ED visits met inclusion criteria. Overall mortality decreased significantly across supervision cohorts ("Direct" 3.8%, "Indirect" 3.3%, "Independent" 2.6%, $p<0.001$), but so too did the rates of patients who presented with ≥3 abnormal vitals ("Direct" 32%, "Indirect" 19%, "Independent" 13%, $p<0.001$). After controlling for vital sign abnormalities, "Direct" and "Indirect" supervision were both significantly associated with reduced OR for mortality ("Direct": 0.57 [0.37-0.90], "Indirect": 0.71 [0.55 -0.92]) when compared to "Independent Care". Sensitivity analysis showed that this mortality benefit was significant for the minority of patients (17.2%) with ≥3 abnormal vitals ("Direct": 0.44 [0.22-0.85], "Indirect": 0.60 [0.41 -0.88]), but not for the majority (82.8%) with 2 or fewer abnormal vitals ("Direct": 0.81 [0.44-1.49], "Indirect": 0.82 [0.58 -1.16]).

Conclusions: Emergency medicine physician supervision of emergency care non-physician clinicians is independently associated with reduced overall mortality. This benefit appears restricted to the highest risk patients based on abnormal vitals. With over 80% of patients having equivalent mortality outcomes with independent non-physician clinician emergency care, a synergistic model providing variable levels of emergency medicine physician supervision or care based on patient acuity could safely address staffing shortages.

Strengths and limitations of this study

- Data from the largest and longest-standing emergency care patient database with mortality outcomes, as well as the only database of emergency care outcomes for non-physician clinician care, published to date in Africa.
- The transition from physician-supervised to independent non-physician clinician care generated a unique natural experiment.
- This is a single-site study conducted at a rural, district-level hospital.
- Patient-level physician supervision data is lacking.
- Logistic regression models are only partially able to control for the changing baseline of population health during the study period.

INTRODUCTION

Global recognition of the need to develop emergency care is growing. [1,2] In low- and middle-income countries (LMIC), physician shortages make the provision of medical care and in particular emergency care problematic, with the greatest challenge centred in Sub-Saharan Africa (SSA). [3–5] Emergency care needs remain largely unmet throughout many LMICs, including Uganda. [5–8] Based on the estimate that 57% of deaths occurring in low-income countries are from conditions treatable with emergency care, approximately 160,000 Ugandans' lives could have been saved by provision of emergency care in 2019. [9,10] Emergency care in Uganda is largely limited by physician shortages, as there are 1.68 physicians per 10,000 people, amongst the lowest rates worldwide. [11]. Uganda has placed a priority on developing emergency care over the next five years, estimating that 454 specialist emergency care physicians will be required by 2025. [12] Emergency care specialty training in Uganda began in 2017 and currently certifies between five and 10 Ugandan emergency medicine specialists per year.[13] This leaves an enormous training gap with between 45 and 90 years of training needed to produce emergency medicine specialists to meet the projected five-year staffing demands.

One solution to address physician shortage that has been widely advocated and implemented in SSA is "task-sharing," or delegating tasks to cadres of new or existing providers, often non-physician clinicians, who do not have the broad-ranging, expensive and lengthy training of physicians. [14–20] The World Health Organization advocates for non-physician clinicians that are "adequately trained, supported and supervised". [18,20] Though non-physician clinicians are currently providing surgical specialty, obstetric, and HIV care throughout SSA [21–27], there has been limited application of non-physician clinician cadres to offset emergency care provider shortages. [19,28,29] High-income countries have compensated for regionally inadequate physician numbers and uneven distribution of emergency physicians by adopting physician supervised non-physician clinicians in larger emergency units and in some cases non-physician clinician practice with remote physician supervision in smaller rural hospitals. [30–33] Data and protocols to guide implementation of emergency care non-physician clinician training and practice in LMICs, where emergency medicine is largely newly developing, and emergency medicine physicians are typically not available, is highly limited.

Few studies exist addressing training of non-physician clinicians for roles in the African acute care settings outside of trainings focused on specific obstetric, surgical or anesthesia procedures [34–37], while others find that emergency and acute care training is lacking in non-physician clinician education in many SSA countries including Uganda. [34,38] There are documentation a few short-courses designed to teach non-physician clinicians emergency care skills in SSA. [39–42] While our research group has published on an emergency care non-physician clinician training program and its associated outcomes, we are not aware of any additional studies documenting a comprehensive emergency care non-physician clinicians training program in a LMIC. [29,43–48] Consistent with this limited evidence base, no standards exist describing if, when or how to transition to reduced supervision or independent non-physician clinician care following initial training. This represents a major limitation in the ability to implement non-physician clinician training, supervision and uptake into health systems in a safe, effective and evidence-based manner.

While health systems are evolving in Uganda over the last decade so too is the health of the general population. Uganda's national crude death rates decreased by 63% across all age groups (10.2/1000 in 2009 to 6.4/1000 persons in 2019) during the study period. [49] Concurrently, life expectancy increased by 6.8 years and rates of malaria and HIV infection decreased. [49] Any longitudinal evaluation of mortality occurring during this time period therefore needs to take into account this changing baseline.

Emergency care has been delivered by non-physician clinicians in Uganda since 2009 in a training program that has transitioned from directly supervised to independent non-physician clinician care. The objective of this study was to test the hypothesis that increasing levels of emergency medicine physician supervision for three cohorts of non-physician clinicians were independently associated with reduced three-day patient mortality. Logistic regression modelling was used to control for the changing baseline health of the Ugandan population. Sensitivity analysis was performed to account for missing data and to attempt to define which populations of patients had mortality outcomes impacted by physician supervision.

METHODS

Study setting

All data comes from the emergency unit at Karoli Lwanga Hospital, a rural district hospital located in the town of Nyakibale in the Rukungiri District of southwest Uganda. The hospital has a six-bed emergency unit that opened in 2008 and treats 300 to 700 patients per month arriving between 8:00 am and midnight every day of the year. Since 2009, the emergency unit has been staffed by non-physician clinicians who received training from emergency medicine physicians working with Global Emergency Care. The non-physician clinicians are nurses who have completed a two-year advanced training course in emergency care described in detail elsewhere by Hammerstedt et al [29]. While the course is currently administered in conjunction with Mbarara University of Science and Technology, the non-physician clinicians in this cohort study were trained as part of the pilot program that began through a collaboration between GEC and Karoli Lwanga Hospital. Global Emergency Care (GEC), a US-based 501(c) [3] non-governmental organization, has run a two-year emergency care specialty non-physician clinician training program since 2009, and currently does so in collaboration with Mbarara University of Science and Technology (MUST).

Supervision of the non-physician clinicians changed over time generating three cohorts: "Direct Supervision", "Indirect Supervision" and "Independent Care". "Direct Supervision"

occurred from November 2009 - April 2010 when a single US-trained emergency medicine physician practicing with a Ugandan license was on site every day and directly supervised non-physician clinician care and supplemented with clinical care in a model similar to US residency training. “Indirect Supervision” occurred from July 2010 - November 2015. During this period a volunteer US-trained emergency medicine physician was on site for approximately 85% of the weeks; however, they were present in a teaching role only and provided no direct patient care. They were available for consultation on an ad hoc basis and consultation was based on non-physician clinician discretion. “Independent Care” occurred from December 2015 - December 2019, and non-physician clinicians provided clinical care without any onsite emergency medicine physician. During the entire study period, no Ugandan physicians were assigned to the emergency unit. Hospital physicians were available in a similar manner throughout the study period for consultation for patients who required surgery, did not respond to initial treatments, or in whom there was considerable diagnostic uncertainty. Throughout the study period, non-physician clinicians admitted patients to the same hospital medical and surgical wards, which were staffed by Ugandan physicians with standard levels of training and no connection to GEC. Resource availability was constant over the study period and with resource utilization by clinicians in this emergency unit described in detail elsewhere. [43]

Patient and public involvement

The non-physician clinician training program was originally developed in response to several years of clinical emergency medicine experience and ongoing healthcare staffing shortages in Uganda. The positive response of patients, staff and administrators at Karoli Lwanga Hospital to the training program and their interest in improving patient care led to ongoing research and program evaluation. Patients and the public were not involved in the design of the study; however, outcome measures are explicitly patient-oriented. Results have been and will continue to be disseminated through open access publications to allow local clinicians, administrators, policymakers and researchers to benefit.

Data collection

GEC maintained a group of trained research associates who prospectively collected quality assurance data on all Karoli Lwanga Hospital emergency unit patient visits. Collected data included demographics, vital signs, laboratory and radiology testing, disposition, as well as three-day follow-up vital status (mortality) for all admitted and discharged patients. On the third day following initial evaluation in the emergency unit, patients admitted to the hospital were visited in person, and patients discharged from the emergency unit or ward were contacted via phone. This follow-up protocol included seven consecutive days of calling all patients on the phone (if they had a phone) before considering them lost to follow-up and is described in detail elsewhere. [29] Ethics approval for the quality assurance database and waiver of consent was obtained through the Institutional Review Board at Mbarara University of Science and Technology (No. 11/08-12). Trained research assistants entered data using Microsoft Excel from 1 January 2010 – 23 March 2012, and Microsoft Access from 24 March 2012 – 31 December 2019.

Data analysis

A cohort study was done using retrospective analysis of prospectively collected data abstracted from the Karoli Lwanga Hospital emergency unit quality assurance database, including all

consecutive patients presenting to the emergency unit from November 2009 until December 2019. All patients missing age, gender, disposition and three-day follow up were excluded from analysis. Patients who were dead on arrival (lacked vital signs with no resuscitation or interventions attempted) and patients who were transferred or left against medical advice did not receive follow-up by protocol and thus were also excluded from analysis. All other patients of all ages and dispositions were included. Age, gender, vital signs, malaria testing, HIV status, gestalt assessment of clinical condition, and year of service were recorded for all patients. Data was abstracted, cleaned, and analysed by a single researcher (BR) using Stata 16.1 (StataCorp, College Station, TX). Missing data was imputed using multiple imputation by chained equations in Stata. Ten datasets were imputed and combined, with disposition and age groups used as auxiliary variables to predict missingness based on the results described below. Because only two months of data existed for 2009, and no data was collected for three months in 2010 while the program transitioned from "Direct" to "Indirect", the years 2009 and 2010 were both coded as 2010 for the continuous "Year" variable included in that model. Twelve variables were included for the final model meeting the minimal criterion of approximately ten events per variable (n=1,169 events overall).[50] All variables with a univariate p-value less than 0.15 were included in the final model. Area Under Receiver Operating Characteristics Curve (AUROC), Hosmer-Lemeshow Goodness of Fit, and Brier score were all calculated for logistic regression models. No a priori power or sample size calculations were performed as all available records were included in analysis. Continuous variables were tested for significance using one-way ANOVA and proportions were compared using chi-squared.

RESULTS

Overall, 49,315 patient visits occurred from 2009 - 2019, and 38,033 (77.1%) met criteria for inclusion for analysis. Inclusion and exclusion criteria are shown in Figure 1.

Patient characteristics stratified by cohorts of patients receiving non-physician emergency care with different levels of emergency medicine physician supervision (as described in Methods above) are shown in Table 1.

Table 1: Patient characteristics

Characteristic	Direct Supervision Cohort (n=1,875)	Indirect Supervision Cohort (n=21,052)	Independent Care Cohort (n=15,106)	P-value
Age, mean (SD)	25.9 (23.5)	28.8 (24.1)	32.9 (24.9)	< 0.001*
Age group				
Under 5 years old, % (n)	26.7% (501)	21.2% (4454)	14.5% (2196)	< 0.001
5-17 years old, % (n)	15.2% (285)	15.8% (3325)	14.7% (2219)	
18-64 years old, % (n)	48.3% (910)	51.7% (10890)	56.5% (8538)	
> = 65 years old, % (n)	9.6% (179)	11.3% (2383)	14.3% (2153)	
HIV-positive, % (n)	1.9% (35)	5.6% (1182)	6.9% (1045)	< 0.001
Malaria parasites on blood smear, % (n)	24.5% (460)	18.5% (3903)	5.6% (848)	< 0.001
Gender - female, % (n)	47.9% (898)	46.2% (9719)	46.6% (7046)	0.29
Complete vital signs				
Under 5 years old, % (n)	36.1% (190)	8.5% (401)	8.5% (205)	<0.001
5-12 years old, % (n)	79.6% (86)	57.8% (758)	49.8% (444)	<0.001
13 years and older, % (n)	88.1% (1092)	87.8% (13163)	90.4% (10672)	<0.001
Vital sign abnormalities				
Blood pressure				
Normal, % (n)	58.2% (1,092)	63.5% (13,368)	72.6% (10,959)	<0.001
Hypotensive, % (n)	21.4% (401)	12.0% (2,528)	7.9% (1,194)	
Missing, % (n)	20.4% (382)	24.5% (5,156)	19.6% (2,953)	
Respiratory rate				

	Normal, % (n)	38.9% (730)	53.5% (11,266)	66.2% (10,000)	
	Tachypnoea, % (n)	52.8% (990)	43.3% (9,121)	27.7% (4,181)	<0.001
	Missing, % (n)	8.27% (155)	3.16% (665)	6.12% (925)	
Oxygen saturation					
	Normal, % (n)	83.7% (1,569)	80.6% (16,965)	84.2% (12,722)	
	Hypoxic, % (n)	13.2% (248)	12.0% (2,533)	12.7% (1,915)	<0.001
	Missing, % (n)	3.1% (58)	7.4% (1,554)	3.1% (469)	
Heart rate					
	Normal, % (n)	48.9% (971)	62.5% (13,161)	64.2% (9,703)	
	Tachycardic, % (n)	49.0%. (918)	36.6% (7,695)	33.8% (5,112)	<0.001
	Missing, % (n)	2.1% (40)	0.9% (196)	1.93% (291)	
Temperature					
	Normal, % (n)	38.4%. (719)	55.3% (11,646)	54.6% (8,250)	
	Hypothermic, % (n)	35.7%. (670)	27.5% (5,779)	29.4% (4,444)	<0.001
	Febrile, % (n)	22.4% (420)	15.7% (3,304)	13.6% (2,049)	
	Missing, % (n)	3.5% (66)	1.5% (323)	2.4% (363)	

*ANOVA used for significance test; all others use chi-squared.

There were significant differences in every characteristic across the cohorts except for gender. As the study progressed there were fewer paediatric patients, more adult and elderly patients, fewer patients with malaria, more patients with HIV, and more patients with abnormal vitals. Missingness was relatively low for all vital signs (0.9% - 8.3%) except blood pressure which had a much higher rate of missingness (19.6% - 24.5%). That missingness was almost entirely restricted to the paediatric population (0-5 Years Old: 88.6% [n=6,803] missing blood pressure, 6-12 Years Old: 39.9% (n=922] missing blood pressure, 13 Years and Older: 2.7% [n=766] missing blood pressure).

The three-day mortality for the program overall (2009-2019) was 3.1% (n=1,169 deaths), and mortality decreased significantly as the program transitioned from "Direct Supervision" to "Indirect Supervision" to "Independent Care" (3.8% [n=72], 3.3% [n=698], 2.6% [n=399] respectively, $p<0.001$). Simultaneously, across those time periods patients presented with significantly fewer abnormal vital signs (Figure 2). Over the entire program, mortality increased monotonically with each additional abnormal vital sign (Zero Abnormal = 0.7% [n=66], One Abnormal=1.7% [n=222], Two Abnormal=3.4% [n=321], Three or more=8.6% [n=561], $p<0.001$).

Given this changing baseline in patient mortality and prevalence of vital sign abnormalities, a logistic regression model was developed to determine whether "Direct Supervision" and/or "Indirect Supervision" was independently associated with increased or decreased mortality as compared to "Independent Care".

The development of this model incorporated the finding that there was a strong association with missing vital signs and mortality with a monotonic increase in mortality for each missing vital sign (Zero Missing: 2.7% [n=746], One Missing: 3.3% [n=319], Two Missing: 7.0% [n=66], Three or more Missing:7.5% [n=38], $p<0.001$). The highest mortality population ("Expired in ED" with 100% mortality) had over half the patients (55.4%, n=103) missing one or more vitals. Therefore, when we attempted complete case analysis for logistic regression, only 70.7% of patients (n=26,869) were included in the model (including only 9.7% of children under five years old) and only 63.4% (n=741) of deaths were included. Therefore, complete case analysis was rejected in favour of multiple imputation (complete case analysis results are available as Appendix 1 and Appendix 2).

Using multiple imputation by chained equations over ten datasets (as described in Methods), we were able to produce a logistic regression model that included all 38,033 patients (Table 2).

Table 2: Logistic regression model of mortality comparing supervision cohorts

	Multiple Imputation (n=38,033)		
	OR	95% CI	p-Value
Age group			
Under 5 years old	1.29	0.77 - 1.14	0.008
5-12 years old	0.49	0.55 - 0.90	<0.001
18-64 years old	REF		
>=65 years old	1.63	1.37 - 1.93	<0.001
HIV			
Negative	REF		
Positive	1.84	1.51 - 2.25	<0.001
Malaria			
Negative	REF		
Positive	0.93	0.78 - 1.12	0.708
Gender			
Male	REF		
Female	0.71	0.62 - 0.80	<0.001
Oxygen saturation			
Normal	REF		
Hypoxic	2.95	2.55 - 3.41	<0.001
Respiratory rate			
Normal	REF		

Tachypnoea	1.82	1.58	-	2.11	<0.001
Heart rate					
Normal	REF				
Tachycardic	1.18	1.03	-	1.36	0.02
Blood pressure					
Normotensive	REF				
Hypotensive	1.65	1.39		1.96	0.027
Temperature					
Normal					
Hypothermic	2.09	1.81	-	2.42	<0.001
Febrile	0.80	0.66	-	0.98	0.034
Year	0.90	0.86	-	0.95	<0.001
Clinical impression					
"Not Sick"					
"Sick"	4.81	3.91	-	5.90	<0.001
"Toxic"	35.6	27.8	-	45.5	<0.001
Supervision					
Independent	REF				
Direct	0.57	0.37	-	0.90	0.015
Indirect	0.71	0.55	-	0.92	0.01

This model had excellent discrimination (AUROC: 0.87 [0.85 – 0.88]), goodness of fit (Hosmer-Lemeshow: 0.991) and accuracy (Brier score: 0.0256). This model found that both "Direct" and "Indirect" supervision were significantly independently associated with reduced OR for mortality ("Direct": 0.57 [0.37-0.90], "Indirect": 0.71 [0.55 -0.92]) when compared to "Independent Care". As a sensitivity analysis, patients with and without three or more abnormal vital signs were analysed separately (Figure 3).

For the minority of patients with three or more abnormal vital signs (17.2%, n=6,451), both "Direct" and "Indirect" supervision were significantly independently associated with reduced OR for mortality ("Direct": 0.44 [0.22-0.85], "Indirect": 0.60 [0.41 -0.88]). However, for the majority of patients who had two or fewer abnormal vital signs (82.8%, n=31,492) there was no significant difference in OR for mortality ("Direct": 0.81 [0.44-1.49], "Indirect": 0.82 [0.58 -1.16]).

DISCUSSION

This study of a non-physician clinician emergency care training program in rural Uganda demonstrates that direct and indirect supervision by emergency medicine physicians reduced overall mortality as compared to independent non-physician clinician emergency care. Sensitivity analysis showed this benefit was restricted to the most severely ill subset of patients – as defined by abnormal vitals – with independent non-physician clinician care having similar outcomes to physician-supervised care for the vast majority of patients. These findings are consistent with a prior study by our author group showing the mortality benefit for direct emergency medicine physician supervision was restricted to the most severely ill subset of children under 5 years of age [46]. We are not aware of any other studies addressing mortality rates of patients cared for by emergency care specialty trained non-physician clinicians in similar LMIC settings. This finding has potentially profound implications for policy to maximize workforce potential in the rapidly developing field of emergency care in Uganda and in similar settings.

One of the fundamental challenges of our analysis was the rapidly changing background of the health system in Uganda during the study period (2009-2019). Many of the most profound shifts seen in our study likely reflect the overall changes in Ugandan health care. As shown in Figure 2, overall mortality significantly ($p<0.001$) decreased by almost 70% during the study period. While impressive, this finding is consistent with the 63% reduction in national crude death rate during the study period [49]. Similarly, we saw many demographic shifts in our population over time (Table 1) including fewer emergencies in children under 5, more elderly patients and reduced rates of malaria. Again, these are consistent with Ugandan national trends over that time period.[49]

Logistic regression models were developed control for confounding variables. As mentioned in Results, high rates of missing data for the highest mortality patients and children under five years old made complete-case analysis a poor fit for our data set. Multiple imputation was eventually selected as the optimal method for handling missing data.[51,52] Single (deterministic) imputation models were developed but ultimately discarded based on poor performance. The multiple imputation model had excellent characteristics (discrimination, goodness of fit, and accuracy) and showed that both "Direct Supervision" and "Indirect Supervision" reduced program mortality overall as compared to "Independent Care". This is an

expected finding, as no argument exists in this manuscript or elsewhere suggesting complete equality between physician and non-physician clinician training, practice or outcomes. Rather, this finding clearly highlights the importance of the scaling-up of the ongoing emergency medicine physician training efforts in Uganda to reduce mortality in emergencies nationwide.

While emergency medicine physician care for all emergency patients is ideal, the current rate of emergency medicine specialist training, health system funding, and high demand for emergency medicine specialist physicians at training institutions and in administrative roles, means that the ideal of emergency medicine specialist clinical care in emergency units throughout Uganda may be decades away from being realized. Therefore, optimizing the role of non-physician clinicians can help address the current gap between emergency care patients and providers.

Sensitivity analysis was performed to attempt to identify which subset of patients might benefit most from physician supervision. With prior studies showing the benefit of direct physician supervision of non-physicians was limited to severely ill pediatric patients, our sensitivity analysis involved stratifying by vital signs.[46] We found that minority of patients with three or more abnormal vital signs (16.7%, n=6,541) had significantly reduced OR of mortality, and that reduction was enough to create a significant mortality impact for those supervision cohorts overall. However, when the majority of patients with two or fewer abnormal vital signs were looked at separately there was no significant reduction in mortality when comparing either “Direct Supervision” or “Indirect Supervision” to “Independent Care”. We believe this finding could be used at triage to immediately identify patients most likely to receive benefit from emergency medicine physician supervision in clinical situations where that resource is too limited to be provided for all patients.

We strongly support the ongoing development of emergency medicine specialty training for physicians in Uganda to help achieve the ultimate goal of providing emergency medicine physician clinical care for all patients. However, current emergency care staffing shortages in Uganda and elsewhere in Sub-Saharan Africa are likely to persist for decades to come. Augmenting the physician workforce with emergency care specialty-trained non-physician clinicians — who can be trained more rapidly, at a lower cost, and are more likely to work in rural areas — is a clear path forward to addressing the immediate emergency care needs faced by millions of Ugandans today.[3,20,38,53] Our analysis shows that a synergy between these groups is possible: non-physician clinicians can safely deliver independent care for the majority of less severely ill patients without causing excess mortality, while emergency medicine physicians can provide or supervise non-physician clinician care to reduce mortality for the most severely ill subset of patients.

Limitations

This is a single-centre, retrospective study of an emergency unit database. Mortality follow-up was limited to three days. While one week and one month mortality is undoubtedly important, three-day follow-up was chosen both to minimize loss to follow-up in a setting where most patients do not have consistent ability to receive phone calls and because follow-up after three days was thought to be less reflective of outcomes related to acute care provided in the emergency unit. Inpatient mortality was affected not just by emergency unit care but also by hospital ward care. However, this care was provided similarly throughout the study, making it unlikely to bias outcomes in comparisons between cohorts. Multiple imputation is a widely accepted method for dealing with missing data, but even with auxiliary variables used to improve the likelihood of meeting the missing at random assumption, any approach to missing data is

imperfect with multiple imputation being no exception. Lastly, there was a high loss to follow-up in discharged patients over the duration of the study (47.7%, n=8,110). Most of this loss to follow was due to lack of phones for the discharged patients (Had no phone: 82.3%, n=6,592; Invalid number: 6.9%, n=553) with only 10.7% (n=856) being loss to follow up for other reasons. However, with a mortality rate of 0.07% (n=6 deaths in 8,906 discharges) in discharged patients with complete follow-up, it is highly unlikely that the 8,110 discharged patients lost to follow-up represent a significant number of fatal cases excluded from our analysis. The 6.3% loss to follow-up rate for admitted and direct to theatre patients was otherwise considered adequate given the challenges of emergency unit data collection in Sub-Saharan Africa.

CONCLUSIONS

This analysis shows that task-sharing of emergency care specialty-trained non-physician clinicians to address emergency care staffing shortages is both efficient and safe for the vast majority of patient encounters. As Uganda strives to reach the goal of consistent emergency medicine physician coverage of emergency units, operationalizing a hybrid model with emergency medicine physician supervision of otherwise independent non-physician clinician care for the sickest emergency care patients has the potential to save lives. Based on the robust evidence base reported here, our recommendations are as follows:

1. Scale up emergency medicine physician development and training: The highest risk approximately 15% of patients had nearly a 50% reduction in mortality with physician involvement, and direct supervision significantly reduced overall mortality.
2. Increase capacity for emergency care NCP training: emergency care non-physician clinicians provided independent care comparable to care given with emergency medicine physician supervision for approximately 85% of patients over the study period.
3. Create triage protocols for early identification of the highest risk patients: in our analysis patients with three or more abnormal vital signs were most likely to derive benefit from emergency medicine physician clinical care or supervision of non-physician clinician care.
4. Create clear protocols and systems to provide emergency care non-physician clinicians with direct supervision in person or via phone/telehealth consultation by emergency medicine physician for patients at high-risk of mortality.

Contributors

BR, AP, CL & MB contributed to conception or design of the work; BR, AP, CL, PK, RL, SK, CN, SN, LA & MB contributed to the acquisition, analysis, or interpretation of data for the work and drafting the work or revising it critically for important intellectual content; BR, AP, CL, PK, RL, SK, CN, SN, LA & MB provided final approval prior to publication; BR, AP, CL, PK, RL, SK, CN, SN, LA & MB agree to be accountable for accuracy and integrity of all aspects of the work.

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Competing interests

There are no competing interests for any author.

Ethics approval

Mbarara University of Science and Technology (MUST) Research Ethics Committee No. 11/08-12

Data availability statement

Data sharing is not allowed under the study IRB Mbarara University of Science and Technology (MUST) Research Ethics Committee No. 11/08-12.

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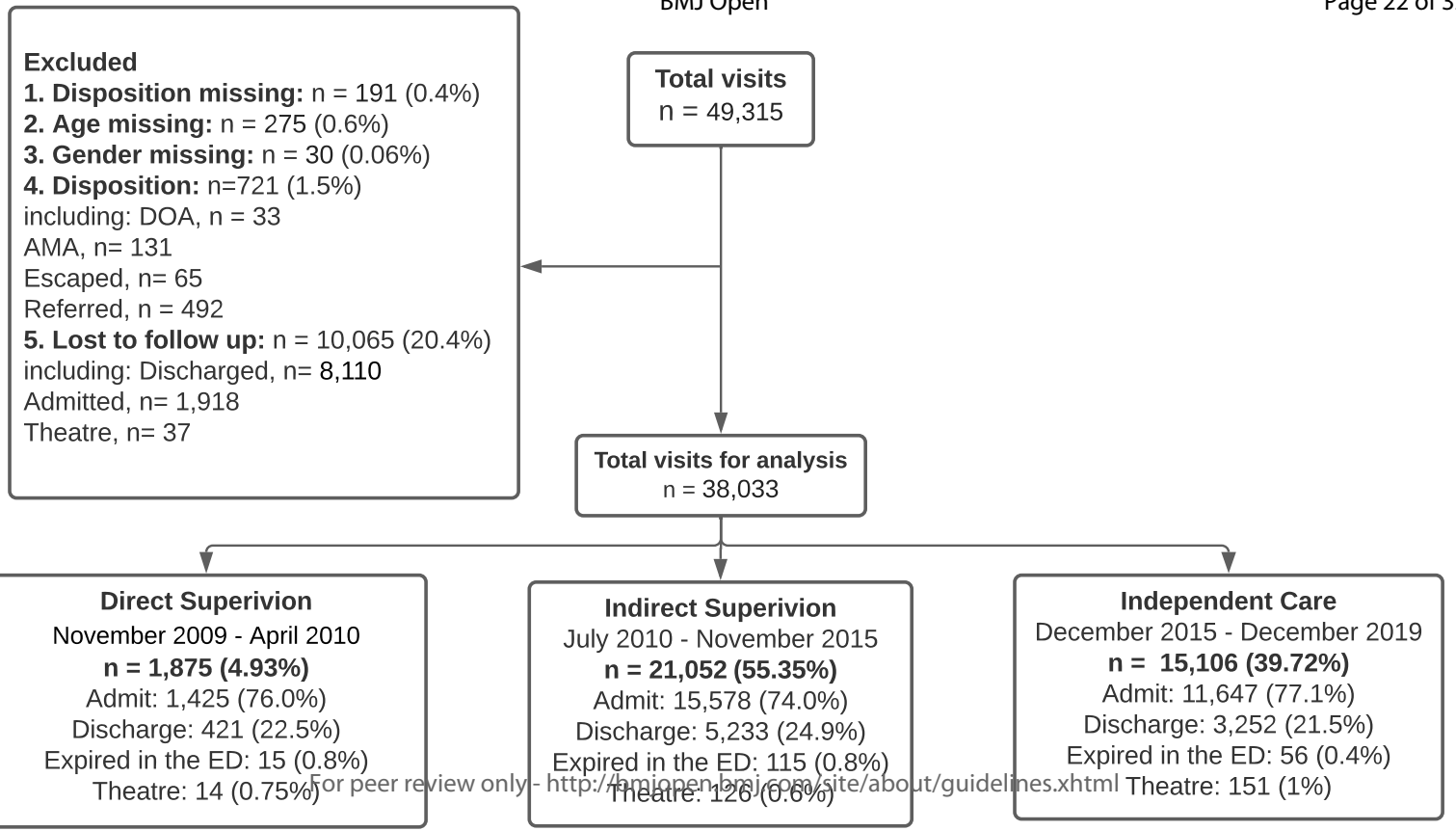
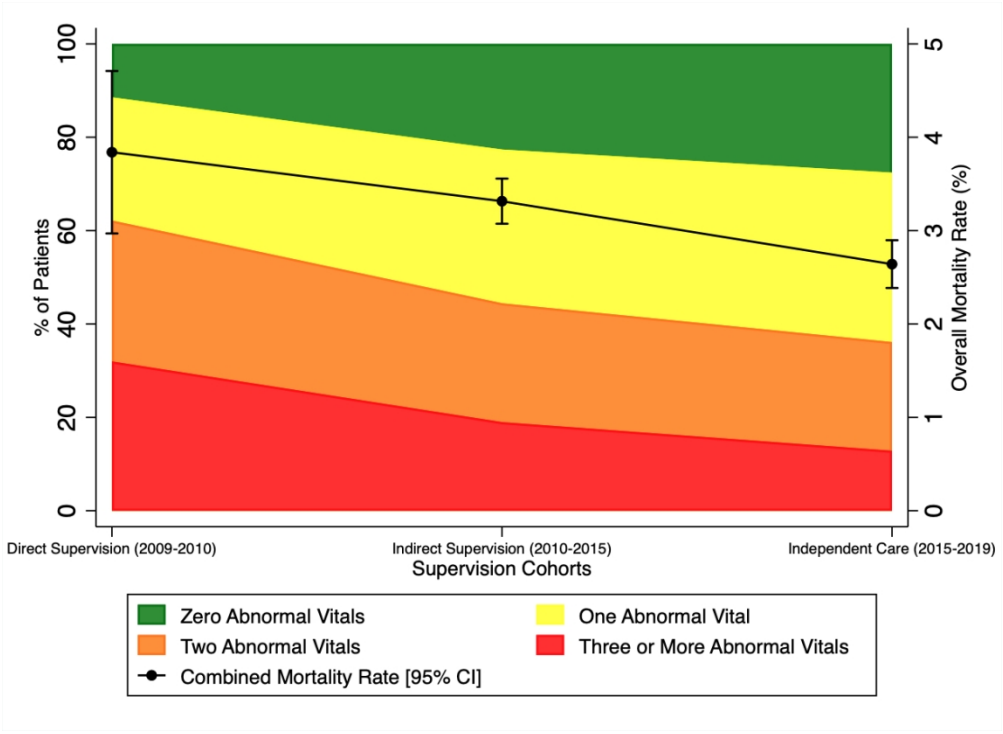
FIGURE TITLES

Figure 1: Patient flow diagram

Figure 2: Mortality and vital sign abnormalities across supervision cohorts

Figure 3: Odds ratios for mortality comparing direct supervision and indirect supervision with independent care





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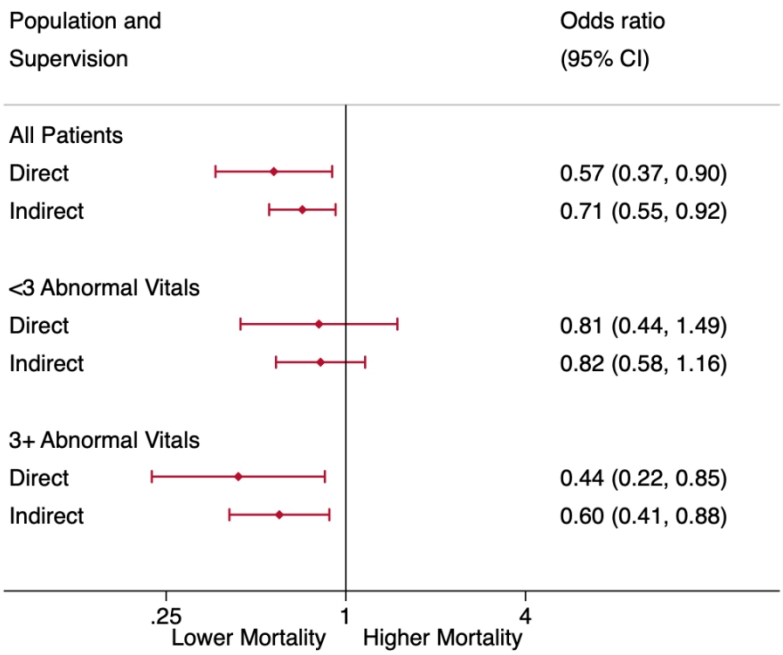

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APPENDIX 1: **Odds Ratios for Mortality comparing Direct Supervision and Indirect Supervision to Independent Care (Complete Case Analysis)**

	Complete Case Analysis (n=26,869)				
	OR	95% CI			p-Value
Age Group					
Under 5	0.60	0.33	-	1.10	0.1
5-12 y.o.	0.52	0.37	-	0.72	<0.001
18-64 y.o.	REF				
>=65 y.o.	1.59	1.31	-	1.91	<0.001
HIV					
Negative	REF				
Positive	1.75	1.40	-	2.19	<0.001
Malaria					
Negative	REF				
Positive	1.08	0.85	-	1.36	0.546
Gender					
M	REF				
F	0.56	0.47	-	0.66	<0.001
Oxygen Saturation					
Normal	REF				
Hypoxic	3.11	2.62	-	3.69	<0.001
Respiratory Rate					
Normal	REF				
Tachypnea	1.92	1.61	-	2.30	<0.001
Heart Rate					
Normal	REF				
Tachycardic	1.30	1.10	-	1.54	0.002
Blood Pressure					
Normotensive	REF				
Hypotensive	1.89	1.58		2.25	<0.001

Temperature					
Normal	REF				
Hypothermic	1.96	1.65	-	2.33	<0.001
Febrile	0.82	0.64	-	1.05	0.119
Year	0.95	0.90	-	1.01	0.101
Clinical Impression					
"Not Sick"	REF				
"Sick"	4.20	3.31	-	5.32	<0.001
"Toxic"	23.2	17.1	-	31.5	<0.001
Supervision					
Independent	REF				
Direct	0.79	0.45	-	1.40	0.42
Indirect	0.77	0.56	-	1.05	0.097

Appendix 2: Odds Ratios for Mortality comparing Direct Supervision and Indirect Supervision to Independent Care

	OR [95% CI]
3+ Abnormal Vitals	
Direct Supervision	**0.61 [0.43 - 0.85]**
Indirect Supervision	0.88 [0.74 - 1.04]
2 Abnormal Vitals	
Direct Supervision	1.63 [0.99 - 2.67]
Indirect Supervision	1.33 [1.02 - 1.73]
1 Abnormal Vital	
Direct Supervision	1.35 [0.61 - 2.98]
Indirect Supervision	**1.44 [1.04 - 2.00]**
0 Abnormal Vitals	
Direct Supervision	2.73 [0.80 - 9.26]
Indirect Supervision	1.17 [0.66 - 2.10]

Bold indicates statistically significant

The RECORD statement – checklist of items, extended from the STROBE statement, that should be reported in observational studies using routinely collected health data.

	Item No.	STROBE items	Location in manuscript where items are reported	RECORD items	Location in manuscript where items are reported
Title and abstract					
	1	(a) Indicate the study's design with a commonly used term in the title or the abstract (b) Provide in the abstract an informative and balanced summary of what was done and what was found		RECORD 1.1: The type of data used should be specified in the title or abstract. When possible, the name of the databases used should be included. RECORD 1.2: If applicable, the geographic region and timeframe within which the study took place should be reported in the title or abstract. RECORD 1.3: If linkage between databases was conducted for the study, this should be clearly stated in the title or abstract.	1
Introduction					
Background rationale	2	Explain the scientific background and rationale for the investigation being reported			3
Objectives	3	State specific objectives, including any prespecified hypotheses			5
Methods					
Study Design	4	Present key elements of study design early in the paper			8
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection			6

Participants	6	*(a) Cohort study* - Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study* - Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study* - Give the eligibility criteria, and the sources and methods of selection of participants *(b) Cohort study* - For matched studies, give matching criteria and number of exposed and unexposed *Case-control study* - For matched studies, give matching criteria and the number of controls per case		RECORD 6.1: The methods of study population selection (such as codes or algorithms used to identify subjects) should be listed in detail. If this is not possible, an explanation should be provided. RECORD 6.2: Any validation studies of the codes or algorithms used to select the population should be referenced. If validation was conducted for this study and not published elsewhere, detailed methods and results should be provided. RECORD 6.3: If the study involved linkage of databases, consider use of a flow diagram or other graphical display to demonstrate the data linkage process, including the number of individuals with linked data at each stage.	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable.		RECORD 7.1: A complete list of codes and algorithms used to classify exposures, outcomes, confounders, and effect modifiers should be provided. If these cannot be reported, an explanation should be provided.	7
Data sources/ measurement	8	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group			7

Bias	9	Describe any efforts to address potential sources of bias			7
Study size	10	Explain how the study size was arrived at			7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why			8
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions (c) Explain how missing data were addressed (d) *Cohort study* - If applicable, explain how loss to follow-up was addressed *Case-control study* - If applicable, explain how matching of cases and controls was addressed *Cross-sectional study* - If applicable, describe analytical methods taking account of sampling strategy (e) Describe any sensitivity analyses			8
Data access and cleaning methods		..		RECORD 12.1: Authors should describe the extent to which the investigators had access to the database population used to create the study population.	9

				RECORD 12.2: Authors should provide information on the data cleaning methods used in the study.	
Linkage		..		RECORD 12.3: State whether the study included person-level, institutional-level, or other data linkage across two or more databases. The methods of linkage and methods of linkage quality evaluation should be provided.	n/a
Results					
Participants	13	(a) Report the numbers of individuals at each stage of the study (*e.g.*, numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed) (b) Give reasons for non-participation at each stage. (c) Consider use of a flow diagram		RECORD 13.1: Describe in detail the selection of the persons included in the study (*i.e.,* study population selection) including filtering based on data quality, data availability and linkage. The selection of included persons can be described in the text and/or by means of the study flow diagram.	9
Descriptive data	14	(a) Give characteristics of study participants (*e.g.*, demographic, clinical, social) and information on exposures and potential confounders (b) Indicate the number of participants with missing data for each variable of interest (c) *Cohort study* - summarise follow-up time (*e.g.*, average and total amount)			10
Outcome data	15	*Cohort study* - Report numbers of outcome events or summary measures over time *Case-control study* - Report numbers in each exposure			11

		category, or summary measures of exposure *Cross-sectional study* - Report numbers of outcome events or summary measures			
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence interval). Make clear which confounders were adjusted for and why they were included (b) Report category boundaries when continuous variables were categorized (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period			11
Other analyses	17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses			15
Discussion					
Key results	18	Summarise key results with reference to study objectives			15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias		RECORD 19.1: Discuss the implications of using data that were not created or collected to answer the specific research question(s). Include discussion of misclassification bias, unmeasured confounding, missing data, and changing eligibility over time, as they pertain to the study being reported.	19
Interpretation	20	Give a cautious overall interpretation of results considering objectives,			20

		limitations, multiplicity of analyses, results from similar studies, and other relevant evidence			
Generalisability	21	Discuss the generalisability (external validity) of the study results			19
Other Information					
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based			n/a
Accessibility of protocol, raw data, and programming code		..		RECORD 22.1: Authors should provide information on how to access any supplemental information such as the study protocol, raw data, or programming code.	n/a

*Reference: Benchimol EI, Smeeth L, Guttmann A, Harron K, Moher D, Petersen I, Sørensen HT, von Elm E, Langan SM, the RECORD Working Committee. The REporting of studies Conducted using Observational Routinely-collected health Data (RECORD) Statement. *PLoS Medicine* 2015; in press.