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ORIGINAL RESEARCH

Adverse events during the intrahospital transfer of critically ill perioperative patients in a South African tertiary hospital

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Background: Critically ill patients frequently require intrahospital transfer for diagnostic or therapeutic procedures, or transfer to the intensive care unit. Intrahospital transfer exposes patients to an increased risk of adverse events. The reported rate of adverse events ranges from 4.2% to 79% based on data from high income countries. There is limited data available on intrahospital transfers in the South African context. This study aimed to determine the incidence of adverse events during intrahospital transfer, the physiological effects of intrahospital transfer, identify potential risk factors for adverse events and determine if adverse events were associated with poor clinical outcomes.
Methods: The study was a single-centre, prospective, observational study of adult patients undergoing transport between the operating theatre and the intensive care unit (or vice versa) of a tertiary academic hospital in South Africa. Demographic data, transfer data (including adverse events, and the physiological parameters of the patients before and after transfer), and intensive care unit outcome data was collected between September 2018 and May 2019.
Results: Data on 94 transfers was collected. Adverse events occurred in 23.4% (95% CI 14.7–32.1%) of transfers. Clinical adverse events, namely hypotension requiring management, made up 55% of the adverse events, while the remaining were technical adverse events (32% monitor failure, 9% ventilator failure and 4% infusion pump failure). The median transfer time was 10 minutes. Patients who developed adverse events during transfer were significantly older (median age 48 years versus 37 years, $p = 0.037$) and were significantly more likely to be receiving inotropic support (81.8% versus 51.4%, OR 4.26; 95% CI 1.31–13.82, $p = 0.011$) than those who did not have adverse events. Only the association with inotropic support remained on multivariable analysis. Patients who suffered an adverse event during transfer had a significantly higher mortality than those who did not have an adverse event (63.6% versus 30.6%, OR 3.98; 95% CI 1.46–10.84, $p = 0.005$) on univariate analysis, however this association was no longer significant on multivariable analysis. Increasing age, inotropic support and transfer by a medical officer as opposed to a registrar remained significant predictors on multivariable analysis. Significant physiological changes were noted in 80.9% of patients, with 64.9% of patients showing deterioration in at least one physiological parameter.
Conclusion: Adverse events are common during the transfer of critically ill patients between the operating theatre and the intensive care unit. Even in the absence of adverse events, physiological changes occur in the majority of patients undergoing transfer. Patients receiving inotropic support are at increased risk of adverse events during transfer and enhanced attention to pre-transfer preparation and intratransfer management is warranted in these patients. The potential associations between adverse events during transfer and transferring personnel and ICU mortality needs to be explored in further studies.

Keywords: intrahospital, transfers, perioperative, tertiary, critically ill

Introduction

Intrahospital transport (IHT) is the transporting of patients within a hospital and is often necessary in critically ill patients for diagnostic or therapeutic purposes. This represents a critical time where the patient is particularly vulnerable to adverse events which could potentially negatively impact on their overall outcome.

Higher income countries such as Germany, Canada and Australia have shown that adverse events do occur during this period of transfer, and that subsequently the critically ill patient may suffer adverse effects such as major physiological derangements, prolonged hospital stay and even death.[1-3] Risk factors for adverse events identified in a large multicentre trial, included physiological derangements such as abnormal pH, partial pressure of carbon dioxide and lactate levels.[4] Data on the transfer of critically ill patients in low- to middle-income countries is limited. Available studies have predominantly explored interhospital transfers (transfer between healthcare facilities), with only one study examining, in part, the effect of IHT on critically ill patients.[5-7] In this study the authors looked at the complication of hypoxaemia during transportation of critically ill patients and showed there was no significant difference in the complication rate between interhospital and intrahospital transfers.[7]

The aim of this study was to describe the incidence of adverse events and the physiological derangements that occur during the IHT of perioperative critically ill patients in a tertiary level hospital in South Africa. We also aimed to identify factors associated with an increased risk of adverse events during transfer and to evaluate whether adverse events during transfer were associated with adverse clinical outcomes.

Methods

The study was a prospective, observational study of patients requiring transport between theatre and the intensive care unit

(ICU) of a tertiary, academic hospital in Durban, South Africa, between 01 September 2018 and 09 May 2019. This hospital is an 852-bedded state-run hospital in an urban area and the study ICU is a multidisciplinary intensivist-run ICU. At the time of the study the ICU bed status had been reduced from 12 to 7 beds due to renovations.

Ethical approval for the study was obtained from the University of KwaZulu-Natal Biomedical Research Ethics Committee (BE 193/18), and subsequently institutional and Department of Health approval were also obtained (KZ_201806_020).

The study population consisted of adult (age over 18 years) patients being transferred from either theatre to ICU or from ICU to theatre during the study period. This specific population group was chosen in order to create a more homogenous sample group, as it had already been shown in a previous study that complication rates during transfer differed significantly by transferring discipline.[7] The study was initially scheduled to be conducted for six months from 01 September 2018. This study period was based on the availability of the principal investigator. It was estimated, based on previous ICU data, that this would allow for data collection on 75–100 transfers. Based on previous data, and a 95% confidence level, a sample size of 91 patients would result in a precision of measurement of the adverse event rate of +/-7.5%.[7] Due to the reduction in ICU bed numbers during the study, recruitment was extended for three months to reach the recruitment target.

At the time of the study, the study ICU and operating theatres were based in different hospital blocks, with the ICU being located on the first floor and the theatres on the ground floor. Transfers thus required both an elevator trip and horizontal movement through general hospital corridors. All transfers involved a minimum of two individuals assisting with the transfer process. This team always included at least one anaesthetic or ICU doctor, and one registered theatre or ICU nurse. The choice of equipment for the ICU transfer was at the discretion of the transferring doctor, but at a minimum included a multiparameter monitor. A transport ventilator was available for use for all transfers if required, as were peristaltic infusion pumps or syringe drivers. A "transfer box" of emergency drugs and airway equipment was required for all transfers from ICU to theatre.

Data was collected using a case-report form which was completed by one of the transporting personnel immediately prior to transfer and on arrival at the destination. Information collected included demographic data, data on the operative procedure, transport data, data on patient condition or physiology, as well as data on any major adverse events. A major adverse event was considered to be any one of the following events: 1) accidental extubation, 2) airway obstruction, 3) hypotension requiring management, 4) new onset arrhythmia, 5) initiation of cardiopulmonary resuscitation, 6) infusion pump failure, 7) monitor failure, and 8) ventilator failure. Items 1 to 5 were classified as major clinical adverse events and items 6 to 8 as major technical adverse events. The physiological condition of the patients before and after transfer, and changes in physiological condition were categorised according to Table I. An increase in category (e.g. from 0 to1) was categorised as a deterioration, while a decrease in category was categorised as an improvement. Pre-transfer data referred to the last values measured prior to the patient's transfer and post-transfer data referred to the first values measured on arrival in either theatre or ICU. The study was non-interventional and thus pre- or post-transfer blood gases were only performed as deemed necessary by the treating physicians, and not for the purposes of the study.

Data were analysed using IBM SPSS Statistics for Windows, Version 25.0. Categorical variables were described as percentages, with a 95% confidence index where appropriate, and compared using the chi-square test or Fisher's exact test, where appropriate. Continuous data were frequently non-normally distributed and were described using median and interquartile ranges (IQR). These data were compared using the Mann-Whitney U test, if data were independent, and the Wilcoxon signed-rank test, if data were paired. A p-value of < 0.05 was deemed statistically significant. Multivariable logistic regression analysis was

Table I: Categorisation of physiological variables

	Category 0: Normal	Category 1: Moderate – Severely ill	Category 2: Critical
Vital signs			
Respiratory rate	12–25	9–11 or 26–29	≤ 8 or ≥ 30
Heart rate	50–110	41–49 or 111–129	≤ 40 or ≥ 130
SBP (mmHg)	90–150	81–89 or 151–179	≤ 80 or ≥ 180
SpO_2 (%)	≥ 95	86–94	≤ 85
Arterial blood gas analysis			
pH	7.35–7.45	7.16–7.34 or 7.46–7.64	≤ 7.15 or ≥ 7.65
PaO_2 (mmHg)	≥ 80	60–79	< 60
$PaCO_2$ (mmHg)	35–45	21–34 or 46–50	≤ 20 or ≥ 51
HCO_3^- (mmol/L)	22–27	11–21 or 28–39	≤ 10 or ≥ 40
Lactate (mmol/L)	< 2	2–4	> 4
Glucose (mmol/L)	4.0–10.0	2.8–3.9 or 10.1–18.0	< 2.8 or > 18

Adapted from Jia et al[4]

conducted for the outcomes of "adverse events during transfer" and "ICU mortality". All risk factors with a univariate association of $p < 0.1$ with the outcome were entered into multivariable analysis, using binary logistic regression. The variable selection procedure was chosen to minimise overfitting of the data. A backward stepwise modelling technique was used, based on likelihood ratios. The odds ratio (OR) for the primary outcome and the 95% confidence intervals (CIs) are reported.

Results

Ninety-four transfers were analysed. Demographic data for the cohort and data regarding the transfers are provided in Table II. The majority of the transfers were from the operating theatre to ICU and were predominantly for emergency abdominal procedures. The median transfer time was 10 minutes, with a range of 3 to 40 minutes, with transferring personnel relatively

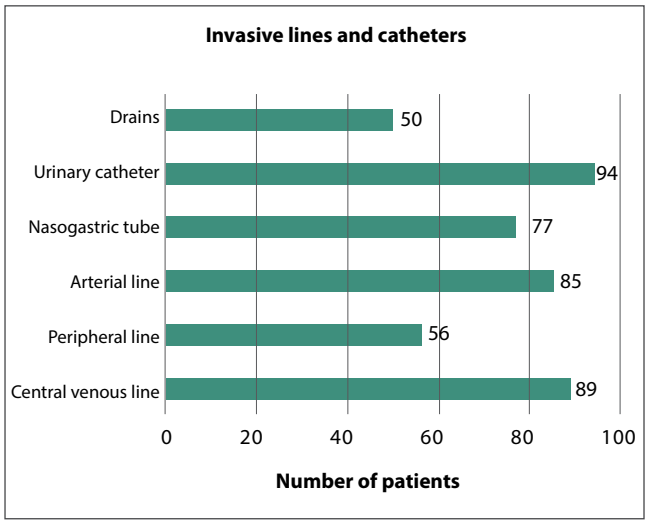

Figure 1: Invasive lines and catheters in transported patients

Table II: Patient demographic data and transfer data and associations with adverse events

		Total	No adverse events (*n* = 72)	Adverse events (*n* = 22)	
		Median (IQR) or n (%)	***Median (IQR) or n (%)***	***Median (IQR) or n (%)***	***p-value***
Age (years)		38 (31–52)	37 (30–47)	48 (33–55)	0.037
Male gender		61 (64.9%)	47 (65.3%)	14 (63.6%)	0.888
Surgical discipline	*ENT*	2 (2.1%)	2 (2.8%)	0 (0.0%)	1.000
	General surgery	82 (87.2%)	62 (86.1%)	20 (90.9%)	
	Gynaecology	4 (4.3%)	3 (4.2%)	1 (4.5%)	
	Obstetrics	1 (1.1%)	1 (1.4%)	0 (0.0%)	
	Orthopaedics	5 (5.3%)	4 (5.6%)	1 (4.5%)	
Surgical procedure	*Intra-abdominal*	71 (76.3%)	55 (77.5%)	16 (72.7%)	0.131
	Airway	10 (10.8%)	6 (8.5%)	4 (18.2%)	
	Skin/soft tissue/bone	5 (5.4%)	5 (7.0%)	0 (0.0%)	
	Thoracotomy	4 (4.3%)	4 (5.6%)	0 (0.0%)	
	Vascular	3 (3.2%)	1 (1.4%)	2 (9.1%)	
Nature of operation performed	*Non-trauma*	53 (56.4%)	40 (55.6%)	13 (59.1%)	0.770
	Trauma	41 (43.6%)	32 (44.4%)	9 (40.9%)	
Urgency	*Elective*	13 (13.8%)	10 (13.9%)	3 (13.6%)	1.000
	Emergency	81 (86.2%)	62 (86.1%)	19 (86.4%)	
Transporting personnel	*Consultant*	38 (40.9%)	31 (43.7%)	7 (31.8%)	0.566
	Medical officer	27 (29.0%)	19 (26.8%)	8 (36.4%)	
	Registrar	28 (30.1%)	21 (29.6%)	7 (31.8%)	
Transport details	*ICU→OT*	21 (22.3%)	15 (20.8%)	6 (27.3%)	0.564
	OT→ICU	73 (77.7%)	57 (79.2%)	16 (72.7%)	
Time in transit (mins)		10 (5–15)	10 (5–15)	9 (5–10)	0.413
Mode of ventilation for transport	*Bag-valve manual ventilation*	22 (23.4%)	18 (25.0%)	4 (18.2%)	0.897
	Face-mask ventilation	5 (5.3%)	4 (5.6%)	1 (4.5%)	
	Mechanical transport ventilation	65 (69.1%)	48 (66.7%)	17 (77.3%)	
	Other	2 (2.1%)	2 (2.8%)	0 (0.0%)	
Inotropic/vasopressor support		55 (58.5%)	37 (51.4%)	18 (81.8%)	0.011
Sedation given		53 (57.0%)	42 (59.2%)	11 (50.0%)	0.449
Analgesia given		50 (53.2%)	38 (52.8%)	12 (54.5%)	0.884

n – number, IQR – interquartile range, ICU – intensive care unit, OT – operating theatre

evenly distributed between consultants (40.9%), registrars (30.1%) and medical officers (29.0%).

Major adverse events occurred in 22 (23.4%, 95% CI 14.7–32.1%) transfers. Hypotension requiring management was the most frequent adverse event, occurring in 12 (55%) patients, and was the only major clinical adverse event noted. The remaining adverse events were technical adverse events and included monitor failure in seven (32%) patients, ventilator failure in two (9%) patients and infusion pump failure in one (5%) patient. While the infusion pump failure occurred in a patient on inotropic support, this did not lead to hypotension requiring management. The management of invasive lines and catheters during IHT was also investigated. The number of patients with different invasive lines and hollow-lumen devices is noted in Figure 1. Five (9%) peripheral lines, one (1%) arterial line and one (1%) nasogastric tube were accidentally removed in transit.

Table III: Change in physiological categories* during transfer in entire cohort and in patients with and without adverse events

		Total	No adverse events	Adverse events	
		n (%)	*n (%)*	*n (%)*	*p-value*
Change in physiological categories	*Deteriorated*	25 (26.6%)	16 (22.2%)	9 (40.9%)	
	Improved	15 (16.0%)	10 (13.9%)	5 (22.7%)	
	Improved and deteriorated	36 (38.3%)	32 (44.4%)	4 (18.2%)	0.089
	No change	18 (19.1%)	14 (19.4%)	4 (18.2%)	
Any vital sign deterioration	*No vital deterioration*	33 (35.1%)	24 (33.3%)	9 (40.9%)	
	Deterioration in any vital sign	61 (64.9%)	48 (66.7%)	13 (59.1%)	0.515

*Change in category according to Table I

Table IV: Vital signs and blood gas parameters before and after transfer

Pre-transfer variable	Total	No adverse events	Adverse events		Post-transfer variable	Total	No adverse events	Adverse events		
	Median (IQR) or n (%)	*Median (IQR) or n (%)*	*Median (IQR) or n (%)*	*p-value#*		*Median (IQR) or n (%)*	*Median (IQR) or n (%)*	*Median (IQR) or n (%)*	*p-value#*	*p-value (pre vs post comparison)*
Systolic BP (mmHg) n = 94	123 (112–134)	124 (112–135)	121 (110–127)	0.330	***Systolic BP (mmHg) n = 94***	128 (110–139)	132 (111–143)	122 (110–136)	0.221	0.033
Diastolic BP (mmHg) n = 94	69 (60–80)	68 (60–80)	72 (63–82)	0.335	***Diastolic BP (mmHg) n = 94***	73 (67–85)	75 (66–90)	71 (67–78)	0.169	0.003
HR (beats/min) n = 94	119 (100–130)	119 (100–134)	117 (104–129)	0.494	***HR (beats/min) n = 94***	120 (101–138)	120 (101–140)	115 (101–136)	0.561	0.026
Temperature (ºC) n = 16	37 (37–39)	37 (37–39)	38 (36–39)	0.913	***Temperature (ºC) n = 12***	37 (37–38)	37 (36–37)	38 (38–39)	0.109	0.655
SpO_2 n = 94	100 (98–100)	100 (98–100)	99 (98–100)	0.656	***SpO_2 n = 93***	99 (97–100)	99 (96–100)	99 (98–100)	0.567	0.015
RR (breaths/min) n = 90	16 (14–18)	16 (14–18)	15 (14–16)	0.482	***RR (breaths/min) n = 88***	16 (14–19)	16 (14–18)	16 (15–19)	0.620	0.164
pH n = 84	7.31 (7.21–7.40)	7.33 (7.21–7.40)	7.28 (7.19–7.40)	0.614	***pH n = 76***	7.32 (7.21–7.40)	7.33 (7.20–7.41)	7.3 (7.21–7.36)	0.363	0.353
$PaCO_2$ (mmHg) n = 84	46 (40–52)	46 (40–52)	46 (40–56)	0.403	***$PaCO_2$ (mmHg) n = 77***	45 (39–52)	45 (39–51)	44 (36–54)	0.927	0.607
PaO_2 (mmHg) n = 82	138 (92–178)	145 (92–184)	122 (89–163)	0.333	***PaO_2 (mmHg) n = 76***	157 (105–205)	152 (89–205)	187 (137–203)	0.215	0.003
FiO_2 (%) n = 81	49 (40–60)	50 (40 - 60)	42 (40–60)	0.547	***FiO_2 (%) n = 74***	60 (40–90)	60 (40–90)	60 (50–85)	0.463	0.011
HCO_3^- (mmol/L) n = 84	23.1 (19.1–28.1)	23.3 (19.1–28.4)	22.3 (19.3–27.0)	0.733	***HCO_3^- (mmol/L) n = 77***	22.1 (17.0–26.8)	23.4 (17.2–27.1)	21.6 (15.6–23.2)	0.231	0.334
BE (mmol/L) n = 84	-1.5 (-7.2–5.0)	-1.1 (-7.2–5.5)	-1.7 (-8.3–2.7)	0.529	***BE (mmol/L) n = 77***	-2.1 (-9.7–2.7)	-1.1 (-9.5–2.8)	-4.3 (-9.8–-0.1)	0.367	0.393
Lactate (mmol/L) n = 83	2.4 (1.4–4.7)	2.6 (1.5–4.7)	2.0 (1.1–4.8)	0.386	***Lactate (mmol/L) n = 76***	3.2 (1.7–5.4)	3.3 (1.7–5.5)	2.9 (1.8–4.9)	0.919	0.820
Glucose (mmol/L) n = 83	8.3 (6.6–10.5)	8.0 (6.1–10.6)	8.5 (7.2–10.2)	0.636	***Glucose (mmol/L) n = 75***	9.0 (6.8–12.5)	9.0 (6.3–12.5)	9.4 (7.2–12.5)	0.924	0.025
P/F ratio	308 (171–373)	315 (17–373)	285 (167–359)	0.872	***P/F ratio***	305 (190–410)	305 (190–410)	313 (193–412)	0.978	0.140

*BP – blood pressure, HR – heart rate, SpO_2 – oxygen saturation, RR – respiratory rate, $PaCO_2$ – partial pressure of carbon dioxide, PaO_2 – partial pressure of oxygen, FiO_2 – fraction of inspired oxygen, HCO_3^- – bicarbonate, BE – base excess

p-value for comparison between patients with and without adverse events.

The significant associations with adverse events on univariate analysis were age and the need for inotropic support. Patients who suffered adverse events were older (median age of 48 years versus 37 years, $p = 0.037$) and were more likely to be receiving inotropic support (81.8% versus 51.4%, $p = 0.011$). The association between inotropic support and adverse events persisted on multivariable analysis (OR = 4.26, 95% CI 1.31–13.82), but that for age was no longer significant (Table VI). Of note there was no association between transporting personnel, mode of ventilation, the use of sedation or analgesia, or transfer time and adverse events.

A change in physiological category (as defined in Table I) occurred in 76 (80.9%) patients, with 61 (64.9%) patients displaying a deterioration in at least one parameter (Table III). Table IV displays physiological and biochemical data pre- and post-transfer and compares the variables in patients with and without adverse events during transfer. Systolic and diastolic blood pressures were significantly higher post-transfer. The post-transfer systolic blood pressure was ≥ 160 mmHg in seven (10.9%) patients and ≥ 180 mmHg in five (5.3%) patients, who had not had a blood pressure beyond these thresholds prior to transfer. PO_2 and FiO_2 were both significantly higher post-transfer, however the PaO_2/FiO_2 ratio (P/F ratio) was not significantly different post-transfer. When comparing pre- and post-transfer values only in patients who had adverse events, the PaO_2 ($p = 0.001$) and FiO_2 ($p = 0.045$) were significantly higher post-transfer, and the HCO_3^- was significantly lower ($p = 0.041$).

The mortality rate for the entire cohort was 38.3% (36/94), and the univariate associations with mortality are shown in Table V. There was a significantly higher mortality rate of 63.6% in patients with adverse events as opposed to a mortality rate of 30.6% in patients without adverse events during transport ($p = 0.005$) on univariate analysis. This association was, however, no longer significant on multivariable analysis, OR 3.20 (95% CI 0.84–12.18). The association with age, inotropic support and transporting personnel remained significant on multivariable analysis. With respect to transferring personnel, transfer by a medical officer, had an odds ratio of 7.36 (95% CI 1.62–33.50) for ICU mortality compared to transfer by a registrar.

Table V: Associations with ICU mortality

		Total	Alive	Deceased	
		Median (IQR) or n (%)	***Median (IQR) or n (%)***	***Median (IQR) or n (%)***	***p*-value**
Age (years)		38 (31–52)	33 (28–38)	52 (42–57)	< 0.001
Adverse events during transfer		22 (23.4%)	8 (13.8%)	14 (38.9%)	0.005
Male gender		61 (64.9%)	42 (72.4%)	19 (52.8%)	0.053
Surgical discipline	*ENT*	2 (2.1%)	2 (3.4%)	0 (0.0%)	0.086
	General surgery	82 (87.2%)	49 (84.5%)	33 (91.7%)	
	Gynaecology	4 (4.3%)	1 (1.7%)	3 (8.3%)	
	Obstetrics	1 (1.1%)	1 (1.7%)	0 (0.0%)	
	Orthopaedics	5 (5.3%)	5 (8.6%)	0 (0.0%)	
Surgical procedure	*Intra-abdominal*	71 (76.3%)	42 (72.4%)	29 (82.9%)	0.145
	Airway	10 (10.8%)	6 (10.3%)	4 (11.4%)	
	Skin/soft tissue/bone	5 (5.4%)	5 (8.6%)	0 (0.0%)	
	Thoracotomy	4 (4.3%)	4 (6.9%)	0 (0.0%)	
	Vascular	3 (3.2%)	1 (1.7%)	2 (5.7%)	
Nature of operation performed	*Non-trauma*	53 (56.4%)	24 (41.4%)	29 (80.6%)	< 0.001
	Trauma	41 (43.6%)	34 (58.6%)	7 (19.4%)	
Urgency	*Elective*	13 (13.8%)	11 (19.0%)	2 (5.6%)	0.122
	Emergency	81 (86.2%)	47 (81.0%)	34 (94.4%)	
Transporting personnel	*Consultant*	38 (40.9%)	24 (42.1%)	14 (38.9%)	0.015
	Medical officer	27 (29.0%)	11 (19.3%)	16 (44.4%)	
	Registrar	28 (30.1%)	22 (38.6%)	6 (16.7%)	
Transport details	*ICU→OT*	21 (22.3%)	11 (19.0%)	10 (27.8%)	0.319
	OT→ICU	73 (77.7%)	47 (81.0%)	26 (72.2%)	
Any vital sign deterioration		61 (64.9%)	38 (65.5%)	23 (63.9%)	0.872
Mode of ventilation for transport	*Bag-valve manual ventilation*	22 (23.4%)	14 (24.1%)	8 (22.2%)	0.322
	Face-mask ventilation	5 (5.3%)	5 (8.6%)	0 (0.0%)	
	Mechanical transport ventilation	65 (69.1%)	38 (65.5%)	27 (75.0%)	
	Other	2 (2.1%)	1 (1.7%)	1 (2.8%)	
Inotropic/vasopressor support		55 (58.5%)	25 (43.1%)	30 (83.3%)	< 0.001
Sedation given		53 (57.0%)	32 (55.2%)	21 (60.0%)	0.649
Analgesia given		50 (53.2%)	30 (51.7%)	20 (55.6%)	0.717

Table VI: Multivariable analyses for adverse events and ICU mortality

		OR (95% CI)	*p*-value
1) Adverse events			
Inotropic/vasopressor support		4.26 (1.31–13.82)	0.016
2) ICU mortality			
Age		1.06 (1.01–1.12)	0.015
Inotropic/vasopressor support		4.90 (1.35–17.78)	0.016
Adverse events during transfer		3.20 (0.84–12.18)	0.089
Nature of operation performed (non-trauma surgery)		3.11 (0.87–11.16)	0.082
Transporting personnel	*Registrar*	1	
	Consultant	1.85 (0.42–8.10)	0.027
	Medical officer	7.36 (1.62–33.50)	

Discussion

The study provides data on 94 intrahospital transfers of perioperative critically ill patients. The majority of transfers (77.7%) occurred from theatre to ICU, with only 22.3% taking place from ICU to theatre. The cohort consisted predominantly of young (median age 38 years) patients undergoing emergency (86.2%) intra-abdominal (76.3%) surgery. During transfer 92.5% of patients received assisted ventilation and 58.5% received inotropic support. The transfers were conducted by a variety of personnel, ranging from consultants (40.9%) to registrars (30.1%) and medical officers (29.0%). The transferring personnel would have been from the department of anaesthesia for transfers from theatre to ICU and from the department of critical care for transfers from ICU to theatre. The latter may have included rotating doctors from a variety of base specialties.

The median transfer time was apparently relatively short at 10 minutes, with an IQR of 5 to 15 minutes but with a large range of 3 to 40 minutes. The ICU and theatre complex are generally located in close proximity on the same floor in the study hospital. During the period of this study, the study ICU and theatres were, however, relocated to temporary locations due to renovations. The study ICU was located on the first floor, in a different block to the theatres, which were located on the ground floor. During transfers the transferring team would have needed to negotiate general access hospital areas and wait for use of a single lift. Delays in transfer may be hypothesised to have been due to the abovementioned challenges or due to adverse events during transfer. While the causes of delays in transfers were not recorded specifically in this study, it is noted that of the three patients with transfer times of 30 minutes or more, two reported no adverse events during transfer and one reported hypotension requiring management. While transfers of the critically ill should not be rushed, unnecessarily prolonging the transfer should be avoided. Where possible this includes infrastructural interventions, such as ensuring that ICUs and theatres are in close proximity and on the same floor or have dedicated lifts and/or access areas. In addition, clear operational plans to ensure the efficiency and safety of transfers are required. These may include relatively simple interventions such as having a team member proceed ahead to secure a lift.

The adverse events prespecified in the study protocol occurred in 23.4% of transfers. Of these, 55% were clinically significant hypotension and the remaining 45% represented equipment failure. In addition, seven invasive lines or catheters were removed during transfer. Furthermore, significant physiological changes occurred in 80.9% of transfers, with a deterioration in at least one prespecified physiological parameter occurring in 64.9% of transfers. These findings highlight the fact that the transfer of critically ill patients is a period of enhanced risk for physiological disturbance. While the transfer of critically ill patients should be avoided if possible, this is frequently not feasible and thus interventions to improve the safety of transfers are required. The high rate of equipment failure suggests that attention needs to be focused on both checking equipment adequately prior to transfer, and ensuring that equipment used to transfer critically ill patients is reliable, of good quality, is serviced regularly and has adequate battery life, amongst other considerations. While all critical care transfers require expertise and attention to detail, identifying patients at risk of adverse events will potentially allow for allocation of additional expertise and resources to these patients and for the identification of risk-factor specific interventions. In this study patients requiring inotropic support were at significantly elevated risk of adverse events. This subgroup of patients should thus be transferred by the members of staff with the most expertise in transferring critically ill patients. It may also be reasonable to delay transfer of these patients until haemodynamic stability is ascertained and ensured (where possible), and to consider interventions such as temporarily increasing inotropic support to prevent episodes of hypotension in patients with borderline acceptable haemodynamics prior to transfer.

There was a significant increase in blood pressure and heart rate post-transfer, with 10.9% of patients having a new increase in blood pressure to ≥ 160 mmHg. While not prespecified as an adverse event (with a focus on hypotension), the deleterious effects of acute hypertension are of concern. The reported usage of sedation (57.0%) and analgesia (53.2%) is relatively low, with 25.5% of patients not reported to have received any analgosedation for transfer, and may explain the blood pressure effects noted. Although an unproven hypothesis, it would appear prudent to encourage transferring personnel to ensure that patients receive adequate analgosedation for transfer.

Adequate analgosedation may also reduce the accidental removal of invasive devices. Transferring personnel also need to ensure that invasive devices are adequately secured prior to transfer. While an apparently "minor" complication of transfer, this not only exposes patients to unnecessary risk but also results in unnecessary healthcare expenditure.

An increase in PaO_2 and FiO_2 ratios, without a significant change in P/F ratio, was noted post-transfer. This finding was significant for patients with adverse events, but not for those without events. While difficult to explain, it is potentially related to the transferring personnel increasing FiO_2 as a non-specific safety response to an adverse event.

While the occurrence of adverse events was associated with increased ICU mortality on univariate analysis, this was no longer significant on multivariable analysis. This may be a statistical phenomenon, with the study being underpowered to demonstrate this association at the $p = 0.05$ level. Alternatively, as shown in the multivariable analysis, this may reflect the fact that alternate patient-related factors, namely age and inotropic support are the actual determinants of patient outcome. Patients on inotropic support, for example, have a greater severity of illness, which is their primary determinant of outcome, however due to their haemodynamic instability they are also more likely to have adverse events during transfer. This would make physiological sense, especially if the adverse events were short-lived, rapidly treated, and/or predominantly technical. The association between transfer by a medical officer (as opposed to a registrar) and increased ICU mortality was unexpected in light of the absence of such an association with adverse events during transfer. While not fully explained, this may reflect the impact of different levels of clinical experience on the transfer of the critically ill and have impacted on factors not measured in this study. It may, however, have been a chance finding, with the relatively wide 95% CI being noted. This should be evaluated further in future studies.

As far as the authors are aware, the study is the first to have evaluated adverse events during IHT in South Africa. There are thus no local data with which to compare the study. The majority of studies in the field originate from high income countries and thus the study adds to the limited data on the transfer of critically ill patients in lower and middle-income countries. Internationally adverse events during IHT of critically ill patients have been reported to occur with a frequency of 4.2% to 79%.[1,4,8] A finding of a 23.4% major adverse event rate in this study turned out to be relatively low when compared to other studies in high-income countries, where adverse event rates as high as 79% have been quoted. The previously quoted wide range in event rates is, however, possibly caused by the fact that the different studies were not all conducted in the same manner. Some studies included infants in their cohort, while others included transfers for diagnostic testing. The criteria used for describing adverse events were also inconsistent. A more recent study done in a middle-income country showed an adverse event rate of 39.9%.[9] Although the income setting of the country may be similar to that of this study, the authors used different methods to classify their adverse events. While we observed for specific major adverse events, the aforementioned study classified their adverse events according to the International Classification of Patient Safety of the World Health Organization. Our population group was also more homogenous, as we excluded transfers which occurred from or to places other than the local theatre complex. A previous South African study had already shown that transfers to different areas such as diagnostic centres or emergency departments often involved different health care personnel with different skill sets and experience, and this affected the condition of the patient during transfer.[7]

Taken in totality, the above findings highlight the potential risks associated with IHT. We thus recommend that IHT be undertaken with caution and vigilance, and only when warranted. The risk-benefit ratio for transferring critically ill patients should be considered especially carefully in patients at elevated risk of complications during IHT. The creation, and ongoing training, of dedicated teams responsible for the transfer of critically ill patients would be an ideal goal. While these teams are well established in high income countries, it is unclear whether they are feasible in the South African setting. In the absence of such teams, the transfer of critically ill patients should be conducted by the personnel with the most experience in this field and should be guided by clear operational plans that emphasise practical aspects to facilitate the transfer and also include checks to ensure adequate equipment for transfer, adequate monitoring and adequate contingency plans for when adverse events do occur.

Limitations to the study include the relatively small sample size. This limits the power of the study to determine associations between potential risk factors and adverse events. It also limits the power of subgroup analyses. This was, however, counterbalanced by the homogeneity of the study population, which allowed for differences in transferring personnel and patient selection to be minimised. As a single-centre study the generalisability of the findings may be questioned, however broad themes were able to be identified and further specific areas for future multicentre research are apparent.

Conclusion

Intrahospital transfer of the critically ill is associated with adverse events and physiological disturbance. Patients receiving inotropic support are at increased risk of adverse events during intrahospital transfer. Transfer of the critically ill patient should be conducted by experienced team members with attention being paid to preventing technical complications and anticipating and preempting or rapidly treating clinical adverse events.

Conflict of interest

The authors declare no conflict of interest.

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Ethics

Ethical approval for the study was obtained from the University of KwaZulu-Natal Biomedical Research Ethics Committee (BE 193/18), and subsequently institutional and Department of Health approval were also obtained (KZ_201806_020).

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