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Original Research Article

Diagnostic challenges in critical care management of fluid and electrolyte disturbances in a poor-resource setting: a survey of critical care doctors

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ABSTRACT

Background: To determine the challenges in diagnostic support for adequate fluid and electrolyte (F/E) management in a poor-resource critical care setting.
Methods: This cross-sectional survey was conducted between March and May 2017 in one hundred and four (104) doctors practicing in four tertiary hospitals in North-central Nigeria. These doctors were currently working in Accidents and Emergency Units (A/E), Intensive care Units (ICU) and Children Emergency Units and have worked for at least two months prior to the study. They were given a structured questionnaire to fill and return. The questionnaire among other things, addressed laboratory-related factors that affect management of F/E disturbances.
Results: Unavailability of some laboratory tests, inaccuracy of laboratory results, incomplete test results and delay in obtaining results, hampered F/E management in critical care according to more than 75% of the surveyed doctors. About sixty percent of the doctors reported a turnaround time (TAT) of ≥3 hours for electrolytes and most emergency biochemical tests (except urine dipstick and Blood gases). Also ≤25% of doctors responded that electrolytes and most emergency biochemical tests (except urine dipstick and Blood gases) were offered in the ICU/Emergency unit laboratories. Ten percent or less of doctors reported that electrolytes and the emergency biochemical test were available by Point of care testing (POCT).
Conclusions: There is an urgent need for the managers of healthcare in LMICs to establish functional laboratories in ICUs, explore the use of POCT and build capacity for diagnostic critical care.

Keywords: Critical care, Emergency department, Fluid and electrolytes, Intensive care, Low-middle-income countries, Point of care test

INTRODUCTION

In the setting of intensive care, fluid and electrolyte (F/E) disturbances are among the most common clinical challenges encountered in the critically ill. A variety of clinical conditions commonly seen in intensive care settings including trauma, sepsis and organ system failure (brain damage, heart failure, liver failure and kidney failure) are often complicated by F/E disorders.[1-3] Volume resuscitation is an essential component of patient care in conditions of hypovolemic shock or sepsis. Correction for electrolyte abnormalities is also essential

for optimal recovery. However, available evidences have shown that fluids can have harmful effects on several organ functions, both from excessive amounts of fluids administered and from the non-physiological composition. Liberal fluid administration is associated with adverse outcomes such as prolonged stay in the ICU, higher costs of care and increased mortality.[4-8]

Safe use of fluid and correction of F/E abnormalities therefore has to be guided by accurate, reliable and timely laboratory results. The incorrect estimation of F/E status means that patient management decision will be influenced by inaccurate information on fluid and electrolytes balance.[5] Adequate laboratory support for instance, is essential in order to evaluate and adjust the ongoing resuscitative needs of the critically ill patient. Basic laboratory equipment such as electrolyte, blood gas and chemistry analyzers with reliable results and good turnaround time (TAT) will raise the level of care in a given hospital setting.[9]

Sadly, many critically ill patients of varying underlying conditions die of the effects of fluid and dyselectrolytaemias in the developing countries due to inadequate diagnosis and management.[9,10] Indeed the dire state of acute care in developing countries has been highlighted in several articles in spite of increasing deaths and burden of critical illness in countries.[11-13]

Diagnostic support has been identified as crucial for effective critical care.[14] Unavailability of basic laboratory tests, issues of reliability, timeliness and narrow spectrum of tests required for adequate F/E management have been identified as challenges to the management of the critically ill in poor resource settings.[15] This makes it difficult to properly classify and manage patients using scoring systems or guidelines largely obtained from the resource-rich settings.[16]

Data on critical care capacity and access to both critical care resources and health care professionals are essential for health system planning. Published data on critical care research from resource-limited countries remain sparse, yet much needed.[14,17] Understanding the challenges of F/E management will also guide local adaptation of guidelines obtained from high income countries.

The spectrum and magnitude of the diagnostic challenges to adequate F/E management faced by health workers in Nigerian Healthcare settings has not been well addressed. This study is an attempt to fill this knowledge gap by examining the diagnostic challenges to F/E management. This study is a survey of doctors working in critical care settings in tertiary health centres in the north-central Nigeria.

METHODS

This cross-sectional survey was conducted between March and May 2017 in four tertiary hospitals in North central Nigeria namely Jos University Teaching Hospital (JUTH) in Jos, the capital city of Plateau State; National Hospital Abuja (NHA) in Abuja, the federal capital territory of Nigeria; Federal Medical Centre Keffi, in Keffi, a town in Nasarawa State and Federal Medical Centre, Markudi, in Markudi the capital city of Benue state. These tertiary hospitals receive referrals from other hospitals within the state and adjoining states. They are also centres for training of resident doctors and intern medical doctors. The four tertiary hospitals manage critical ill patients in the Accidents and Emergency Units (A/E), Intensive care Units (ICU) and Children Emergency Units. The NHA also has a Trauma Centre which serves as a National Trauma centre for managing trauma-related cases.

One hundred and four doctors who have worked and/or currently working in these units for two or more months and who consented to participating in this survey were given a structured questionnaire to fill and return. The questionnaires were administered during daily departmental seminar presentations as well as to doctors who were on duty during the period of the study. The questionnaire covered information regarding specialty and level of experience.

Also, the questionnaire addressed frequency of encountering F/E disturbances; laboratory-related factors that affect management of F/E disturbances; Relevance of laboratory test for F/E management; Availability of laboratory test for F/E management and TAT for laboratory test for F/E management to determine the scope of the challenges. The doctors were given the opportunity to rate the magnitude of the problem using a 5-point ordinal scale format in the questionnaire. For the purpose of reporting, “strongly agree” and “agree” were regarded as “agree” while “very relevant” and “relevant” were regarded as “relevant”.

The data collected were compiled in Microsoft Excel® version 2.0 and exported to Statistical Package for Social Sciences (SPSS® Incoporated Chicago Version 18.0) software for analysis. The data were represented in tables and charts. Descriptive statistics were presented as percentages and median with interquartile range (IQR).

RESULTS

This study surveyed doctors of various specialties and levels of experience. A total of 140 questionnaires were administered and 104 returned given a response rate of 74.3%. The minimum and maximum number of years post basic medical qualification (MBBS) was 3 months and 20 yrs respectively with a median (IQR) of 7 (3.3-9) yrs. Most of the respondents were junior medical officers (54.8%). The number of respondents by hospital and specialty are presented in table 1. Almost 99% of all the doctors surveyed encounter F/E disturbances in management of critically ill patients in the intensive care settings. Also, almost all doctors surveyed (99%) agree

that F/E management is crucial for critical care, see Figure 1.

Table 1: General characteristics of respondents.

General characteristics	Frequency (%)
State	
Abuja	33 (31.7)
Benue	23 (22.1)
Nasarawa	18 (17.3)
Plateau	30 (28.8)
Cadre of doctors	
Interns	22 (21.2)
Junior medical officer*	57 (54.8)
Senior medical officer**	25 (24.0)
Specialty of doctors	
Anaesthesia	3 (2.9)
Family physician	12 (11.5)
Internal medicine	11 (10.6)
Obstetrics and gynaecology	3 (2.9)
Paediatrics	17 (16.3)
Surgery	9 (8.7)

Junior Medical Officer* (Medical officers and Registrar)
Senior Medical Officer** (Senior Registrars and Consultants)

The Respondents' perception and/or experience of laboratory factors that affect management of F/E disturbances in the critically ill are summarized in table 2.

About 80% of the doctors surveyed agreed that unavailability of some laboratory tests and inaccuracy of laboratory test results hinder management of the critically ill in their practice.

Incomplete test results and unavailability of test during call hours are a concern for more than 80% of the surveyed doctors in their practice of managing critically ill patients with 43.7% of the doctors expressing strong concern for the unavailability of tests during call hours.

However, 76% of doctors feel that delay in obtaining results hamper management of F/E challenges in their patients and whereas only 60% of the respondent were worried that the cost of laboratory tests has effect on the management of patients with F/E disturbances.

Table 2: Respondents perception/experience of laboratory factors that affect management of fluid and electrolyte disturbance in the critically ill.

	Strongly agree n (%)	Agree n (%)	Uncertain n (%)	Disagree n (%)	Strongly disagree (%)	No response n	Percent Agree (%)
Unavailability of some laboratory test	37 (35.6)	46 (44.2)	2 (1.9)	17 (16.3)	2 (1.9)	0	79.8
Accuracy of laboratory test results	37 (35.6)	47 (45.2)	9 (8.7)	10 (9.6)	1 (1.0)	0	80.2
Incomplete test profiles/results	35 (34.0)	54 (52.4)	6 (5.8)	6 (5.8)	2 (1.9)	1	86.4
Cost of laboratory testing	24 (23.1)	39 (37.5)	19 (18.3)	18 (17.3)	4 (3.8)	0	60.6
Delay in getting laboratory result	37 (35.6)	42 (40.4)	8 (7.7)	17 (16.3)	0 (0)	0	76
Unavailability of some tests during call hours	45 (43.7)	39 (37.9)	8 (7.8)	9 (8.7)	2 (1.9)	1	81.6

The doctors' responses on availability of laboratory tests in the central laboratory, the ICU or Emergency unit laboratory, point of care platform and during call hours is summarized in table 3.

More than 90% of doctors responded that Na^+, K^+, Cl^-, HCO^{3-}, $Ca2^+$, Urea, Creatinine and dipstick urinalysis were provided by their central laboratory. Laboratory test like Lactate (38.3%), Osmometry (28.8%), Blood gases (38.3%), PO_4^{2-} (85.4%), Mg^{2+} (53.7%) and Urine electrolytes (Na^+, K^+, Ca^{2+}, PO_4^{2-}) (50%) were less commonly provided in the central laboratories.

Only about 20-25% of doctors responded that the tests were offered in the ICU or Emergency unit laboratory except lactate (10.3%), Urine electrolytes (Na^+, K^+, $Ca2^+$, PO_4^{2-}; 16.9%) and dipstick urinalysis (61.4%). With the exception of dipstick urinalysis (71.1%), only about 10% of the respondents' reported that these tests were offered by Point of Care Testing (POCT). About 30-50% of the respondents reported that tests such as Na^+, K^+, Cl^-, HCO^{3-}, Urea, Creatinine were not provided during call hours. More than 50% of the respondents' reported that Lactate, Osmometry, Blood gases, $Ca2^+$, PO_4^{2-} , Mg^{2+}, and Urine electrolytes (Na^+, K^+, $Ca2^+$, PO_4^{2-}) were not provided during call hours.

Table 4 shows the doctors perception on the relevance of biochemical tests used for management of F/E disturbances.

Ninety five percent or more of the respondents consider Na^+, K^+, HCO^{3-}, Urea, Creatinine and Blood gases as relevant or very relevant for management of F/E disturbances.

Chloride (88.4%), dipstick urinalysis (80%), Ca (75.8%), lactate (72.6%) and osmometry (70%) were reported as relevant or very relevant for F/E management.

Less than 70% of responding doctors consider Mg^{2+}, PO_4^{2-} and Urine electrolytes (Na^+, K^+, $Ca2^+$, PO_4^{2-}) to be relevant or very relevant for F/E management.

Table 3: Availability of biochemical tests used for management of fluid and electrolyte disturbances.

Laboratory tests	Offered in main/central lab N (%)			Offered in ICU or a/e lab N (%)			Offered by point of care testing N (%)			Offered during call hours N (%)		
	Yes	No	NR*	Yes	No	NR	Yes	No	NR	Yes	No	NR
Na^+	98 (99)	1 (1)	5	22 (25.3)	65 (74.7)	17	9 (10.7)	75 (89.3)	20	62 (67.4)	30 (32.6)	12
K^+	98 (99)	1 (1)	5	21 (24.1)	66 (75.8)	17	8 (9.8)	74 (90.2)	22	61 (58.7)	30 (31.9)	13
Cl^-	97 (99)	1 (1)	6	22 (25.0)	66 (75.0)	16	9 (11.0)	73 (89.0)	22	58 (65.9)	30 (34.1)	16
Hco_3^-	89(91.8)	8 (8.2)	7	20 (23.0)	67 (77.0)	17	9 (10.8)	74 (89.2)	21	52 (57.8)	38 (42.2)	14
Urea	98 (99)	1 (1)	5	19 (21.8)	68 (78.2)	17	8 (9.6)	75 (90.4)	21	60 (65.9)	31 (34.1)	13
Creatinine	93 (94.9)	5 (5.1)	6	18 (20.5)	70 (79.5)	16	9 (10.8)	74 (89.2)	21	56 (62.9)	33 (37.1)	15
Lactate	36 (38.3)	58 (61.7)	13	9 (10.3)	78 (89.6)	17	6 (7.4)	75 (92.6)	23	21 (24.7)	64 (75.3)	19
Osmometry	30 (28.8)	61 (58.7)	13	11 (12.8)	75 (87.2)	18	8 (10.4)	69 (89.6)	27	17 (21.0)	64 (79.0)	23
Arterial blood gas	36 (38.3)	58 (61.7)	13	25 (28.4)	63 (71.6)	16	16 (20.0)	64 (80.0)	24	24 (28.9)	59 (71.1)	21
Ca^{2+}	88 (91.7)	8 (8.3)	8	17 (19.5)	70 (80.5)	17	8 (9.6)	75 (90.4)	21	39 (43.3)	51 (56.7)	14
Po_4^{2-}	82 (85.4)	14 (14.6)	8	18 (20.5)	70 (79.5)	16	7 (8.5)	75 (91.5)	22	37 (41.6)	52 (58.4)	15
Mg^{2+}	51 (53.7)	44 (46.3)	9	12 (13.8)	75 (86.2)	17	6 (7.4)	75 (92.6)	23	28 (32.2)	59 (67.8)	21
Urinalysis (dipstick)	92 (93.9)	6 (6.1)	6	54 (61.4)	34 (38.6)	16	59 (71.1)	24 (28.9)	21	68 (78.2)	19 (21.8)	17
Urine electrolytes (Na^+, k^+, ca^{2+} po_4^{2-}	46 (50.0)	46(50.0)	12	14 (16.9)	69 (83.1)	21	7 (9.3)	68 (90.7)	29	26 (32.9)	53 (67.1)	25

*NR- No Response

Only blood gases (19.1%) and dipstick urinalysis (64.2%) had more than 10% of the doctors were reporting a TAT of within 60 mins as shown in Table 5. Apart from dipstick urine, most doctors (> 60%) reported a TAT of more than 3 hours.

Table 4: Relevance of biochemical tests used for management of fluid and electrolyte disturbances.

Relevance of test Lab test	Very relevant (%)	Relevant N (%)	Somewhat relevant n (%)	Not relevant n (%)	Very irrelevant n (%)	No response n	Percent relevant (%)
Na^+	85 (89.5)	8 (8.4)	2 (2.1)	0 (0)	0 (0)	9	97.9
K^+	89 (92.7)	7 (7.3)	0 (0)	0 (0)	0 (0)	8	100
Cl^-	66 (69.5)	18 (18.9)	10 (10.5)	1 (1.1)	0 (0)	9	88.4
Hco_3^-	80 (83.3)	11 (11.5)	5 (5.2)	0 (0)	0 (0)	8	94.8
Urea	82 (87.2)	11 (11.7)	0 (0)	1 (1.1)	0 (0)	10	98.9
Creatinine	83 (87.4)	9 (9.5)	2 (2.1)	1 (1.1)	0 (0)	9	96.9
Lactate	36 (39.6)	30 (33.0)	22 (24.2)	3 (3.3)	0 (0)	13	72.6
Osmometry	37 (41.1)	26 (28.9)	20 (22.2)	6 (6.7)	1 (1.1)	14	70
Arterial blood gas	57 (62.0)	33 (35.9)	1 (1.1)	1 (1.1)	0 (0)	12	97.9
Ca^{2+}	52 (54.7)	20 (21.1)	18 (18.9)	5 (5.3)	0 (0)	9	75.8
Po_4^{2-}	44 (46.8)	21 (22.3)	24 (25.5)	5 (5.3)	0 (0)	10	69.1
Mg^{2+}	37 (38.9)	27 (28.4)	27 (28.4)	3 (3.2)	1 (1.1)	9	67.3
Urinalysis (dipstick)	58 (61.1)	18 (18.9)	14 (14.7)	5 (5.3)	0 (0)	9	80
Urine electrolytes (Na^+, k^+, ca^{2+}, po_4^{2-})	35 (37.6)	24 (25.8)	25 (26.9)	7 (7.5)	2 (2.2)	11	63.4

Table 5: Turnaround time of biochemical tests used for management of fluid and electrolyte disturbances.

Turnaround time Lab test	≤ 30 mins N (%)	> 30- 60 mins N (%)	> 60- 120 mins N (%)	> 120-180 mins N (%)	> 180 mins N (%)	Neutral N	Percent ≤ 60 mins
Na^+	2 (2.4)	6 (7.1)	18 (21.2)	7 (8.2)	52 (61.2)	19	9.5
K^+	2 (2.4)	6 (7.2)	19 (22.9)	5 (6.0)	51 (61.2)	21	9.6
Cl^-	2 (2.4)	6 (7.2)	18 (21.7)	6 (7.2)	51 (61.2)	21	9.6
Hco_3^-	1 (1.2)	6 (7.4)	17 (21.0)	6 (7.4)	51 (63.0)	23	8.6
Urea	1 (1.2)	5 (6.0)	20 (24.1)	5 (6.0)	52 (62.6)	21	7.2
Creatinine	1 (1.2)	5 (6.0)	18 (21.7)	7 (8.4)	52 (62.6)	21	7.2
Lactate	1 (1.5)	5 (7.5)	8 (11.9)	5 (7.5)	48 (71.6)	37	9
Osmometry	1 (1.6)	5 (8.1)	11 (17.7)	3 (4.8)	42 (67.7)	42	9.7
Arterial blood gas	7 (10.3)	6 (8.8)	8 (11.8)	4 (5.9)	43 (63.2)	36	19.1
Ca^{2+}	0 (0)	7 (8.6)	14 (17.3)	5 (6.2)	55 (67.9)	23	8.6
Po_4^{2-}	1 (1.3)	6 (7.6)	15 (19.0)	5 (6.3)	52 (65.9)	25	8.9
Mg^{2+}	1 (1.4)	5 (7.0)	11 (15.5)	4 (5.6)	50 (70.4)	33	8.4
Urinalysis (dipstick)	38 (46.9)	14 (17.3)	4 (4.9)	1 (1.2)	24 (29.6)	23	64.2
Urine electrolytes (Na^+, k^+, ca^{2+}, po_4^{2-})	2 (3.1)	2 (3.1)	8 (12.5)	3 (4.7)	49 (76.6)	40	6.2

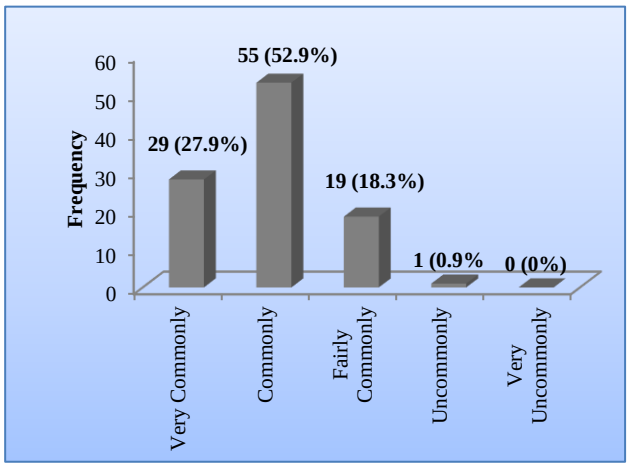

Figure 1: Frequency of encountering fluid and electrolyte disturbances.

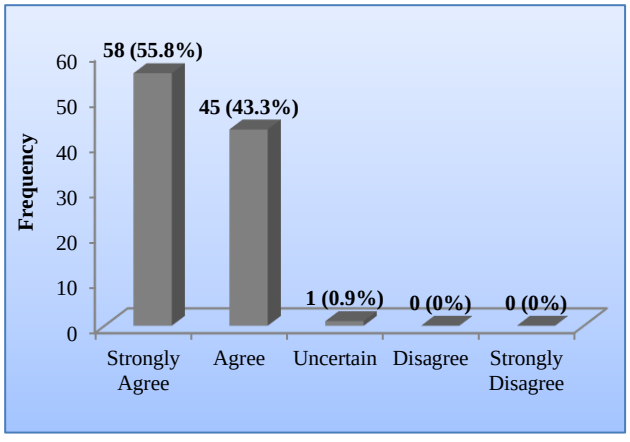

Figure 2: Response as to whether fluid and electrolyte management is decisive for critical care.

DISCUSSION

This study highlights the significance of diagnostic support in the management of F/E disturbances which is often a prominent feature in the critically ill patient. The responses from a wide spectrum of doctors (from the lowest cadre of experience to the highest level of experience obtainable in Nigeria health system) as well as the multicenter nature of this survey makes for a robust representation and therefore applicability of the findings of this study in other resource-limited settings. The responses of the doctors affirm that F/E disturbances are common in the critically ill in Nigeria and their management are very crucial to the survival or outcome in these patients.

The findings from this study suggest that the test menu offered in the laboratory is narrow to support adequate management of F/E abnormalities. Only the traditionally measured electrolytes (Na^+, K^+, Cl^-, HCO^{3-}), markers of kidney function (urea, and creatinine) and dipstick urinalysis are commonly measured in the central laboratories. Laboratory tests such as Mg^{2+}, lactate, osmometry, blood gases and Urine electrolytes (Na^+, K^+, $Ca2^+$, PO_4^{2-} are less commonly measured in central laboratories as reported by the doctors surveyed. This survey has demonstrated that physicians consider these laboratory tests to be relevant or even very relevant for managing F/E derangement in the critical care settings. Although the impact of unavailability of these tests is not known in quantifiable terms, if the assessment of physicians managing critically ill patients in these hospitals is anything to go by, it could be inferred that the unavailability of these tests is likely to have a significant negative impact on the management of critically ill patients in these hospitals.

Even worse, many doctors reported that the laboratory tests were not offered in the ICU or A/E Laboratories. Only about 20-25% of doctors reported that the commonly measured electrolytes, urea and creatinine were available in the ICU or A/E Laboratories. Recently the role of ICU set up in the outcome of critically sick patients has been emphasized.[18,19] Having dedicated critical care delivery has been shown to result in better outcome for the critically injured patient.[18,19] A functional laboratory dedicated for critical settings will be ideal for prompt decision making and management of the critically ill.

The accuracy of laboratory results is crucial for patients care in general and more so for the critically ill. Critically ill patients are particularly prone to developing severe variations in analytes such as electrolytes, bicarbonate, haemoglobin, and glucose concentrations.[20] Several studies have been conducted to assess and compare the reproducibility and accuracy of analyzers used in critical care settings to underline the implications of inaccurate test results on outcome of the critically ill, indeed analytical performance for critical care diagnostic devices are usually very stringent.[20-22] In this survey, 80% of physicians were concerned that inaccurate laboratory results do negatively impact the management of fluid and electrolytes. Regular laboratory audit of all the total testing processes and work flow from pre-analytical to post analytical as well as feedback from physicians to the laboratory will be crucial to achieving set analytical targets for key analytes.

The physiological instability in critically ill patients is reflected by rapid changes in biochemical markers therefore rapid assessment of electrolyte abnormalities is crucial for instituting management of these patients. Timeliness of laboratory results was another cause for concern with regards to managing F/E disturbances in the critically ill. In this survey, the TAT for most analytes were most frequently reported to be more than 3hrs. Less than 10% of the doctors were reporting a TAT of within 60 mins for all the analytes except dipstick urinalysis (64.2%) and blood gases (19.1%).

This is quite a contrast to reports of surveys of TAT for analytes in emergency departments in the developed world. In the United States for instance, Steindel and Howanitz reported that 90% of potassium tests were ordered and reported in 69 minutes or less in Half of laboratories surveyed while STAT chemistry tests had average TAT of less than I hr in 11 hospitals surveyed in another study.[23,24] However, the long TAT appear to be in keeping with what was obtained in a survey in Iran, a developing country. In this study, the TAT for 90% of emergency tests was 3.5 hours while the mean total TAT was 2.28 hours, with a median of 2 hours.[25] Mean TAT of 1-1.5hr was observed for emergency tests in an Indian survey.[26] The long TAT for emergency tests in this study is likely related to the fact that most analytes were not analyzed in ICU or A/E laboratories. Rapid TAT for emergency tests are frequently due to widespread use of POCT.[23,24,27] Critical conditions often require serial monitoring of laboratory results to enable rapid decisions so as to avoid subsequent avoidable complications. POCT is therefore ideally suited for this purpose. Blood gas analyzers have been widely introduced into modern ICUs and many of these devices have capacity for measurement of other biochemical analytes such as electrolytes, urea, creatinine and lactate commonly required in ICU settings.[20,27] The most common POCT used in the ICU in this study was urine dipstick. Only 20% of the doctors reported availability of POCT for Blood gases while ten percent or less of doctors reported that the other analytes were available by Point of care testing.

A significant portion of the respondents (81.6%) agreed that unavailability of some tests during call hours was a key issue in managing their critically ill patients with F/E derangements. Not surprisingly, almost one-third of the respondents reported unavailability of electrolytes during call hours. Infrequently measured analytes or tests like lactate and osmometry were even less commonly available during call hours.

"Incomplete test results" was clearly a worry for most responding doctors. When several tests are ordered, proper interpretation of the results particularly in the context of the critically ill usually requires complete set of results. The consequence of incomplete result may include inaccurate interpretation, delay in instituting treatment and sometimes a need to repeat testing.

One limitation of this survey is that for some test categories, while some doctors reported "availability" of the tests "in the central lab", "in the ICU lab", "during call hours", or "by POCT", other doctors in the same hospital reported "unavailability" of the tests. Therefore, the responses of the doctors may be seen as a reflection of their perception of how accessible these tests are in their practice in intensive care settings. Therefore, this may indicate unreliability of laboratory services or down times rather than outright absence. It may also be due to availability of a functional POCT in one section of the hospital. For instance, the ABG machine may be available in trauma ICU or A/E but not in the main ICU of the same hospital. Notwithstanding, the findings from this study express the diagnostic capacity for managing F/E problems in the critically ill patient in a low-income setting.

CONCLUSION

Although this study was conducted in a poor-resource environment, compared to the aforementioned factors, less proportion of physicians considered "cost of the tests" to be a major obstacle in their experience of managing F/E derangement. This is insightful, suggesting that if other laboratory and extra-laboratory factors are taken care of, there is likely to be an increased utilization

of tests for managing critically ill patients even in this setting. This therefore brings to fore the urgent need of managers of healthcare in low income settings to establish functional laboratories in ICU settings, exploring the use of POCT to build capacity for diagnostic support for critical care.

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