Examining which clinicians provide admission hospital care in a high mortality setting and their adherence to guidelines: an observational study in 13 hospitals

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ABSTRACT

Background We explored who actually provides most admission care in hospitals offering supervised experiential training to graduating clinicians in a high mortality setting where practices deviate from guideline recommendations.

Methods We used a large observational data set from 13 Kenyan county hospitals from November 2015 through November 2018 where patients were linked to admitting clinicians. We explored guideline adherence after creating a cumulative correctness of Paediatric Admission Quality of Care (cPAQC) score on a 5-point scale (0–4) in which points represent correct, sequential progress in providing care perfectly adherent to guidelines comprising admission assessment, diagnosis and treatment. At the point where guideline adherence declined the most we dichotomised the cPAQC score and used multilevel logistic regression models to explore whether clinician and patient-level factors influence adherence.

Results There were 1489 clinicians who could be linked to 53,003 patients over a period of 3 years. Patients were rarely admitted by fully qualified clinicians and predominantly by preregistration medical officer interns (MOI, 46%) and diploma level clinical officer interns (COI, 41%) with a median of 28 MOIs (range 11–68) and 52 COIs (range 5–160) offering care per study hospital. The cPAQC scores suggest that perfect guideline adherence is found in ≤12% of children with malaria, pneumonia or diarrhoea with dehydration. MOIs were more adherent to guidelines than COIs (adjusted OR 1.19 (95% CI 1.07 to 1.34)) but multimorbidity was significantly associated with lower guideline adherence.

Conclusion Over 85% of admissions to hospitals in high mortality settings that offer experiential training in Kenya are conducted by preregistration clinicians. Clinical assessment is good but classifying severity of illness in accordance with guideline recommendations is a challenge. Adherence by MOI with 6 years’ training is significantly better than COI with 3 years’ training, performance does not seem to improve during their 3 months of paediatric rotations.

BACKGROUND

In many African countries physician trainees (medical officer interns (MOI) in Kenya) and non-physician clinic trainees (clinical officer interns (COI) in Kenya) undertake a preregistration internship after preservice training of 6 years at a university and 3 years of technical college, respectively. Typically, they have between 10 and 18 weeks of preservice paediatric ward-based training. In Kenya, the 1-year internship is intended to be a period of hospital-based employment in 1 of over 70 eligible hospitals where practice is carefully supervised prior to professional registration. To provide supervision hospitals that serve as internship centres usually have registered general medical officer (MO) and clinical officer (CO) who have
Study population

Since November 2015, the data clerks have also recorded basic details on all clinicians responsible for paediatric admissions. Data are recorded in a secure separate log and accompanying database. Each clinician is assigned a unique identifier linked to their gender, cadre (MO, CO), whether they were interns (MOI, COI) and their rotation start date (for MOI and COI). At the point of reviewing a patient’s file on discharge, the clerk identifies the admitting clinician and links the patient record to the clinician’s unique identifier.

Study design and data collection

The Kenya Medical Research Institute/Wellcome Trust Research Programme in collaboration with the Kenya Paediatric Association, the University of Nairobi and the Kenya Ministry of Health (MoH) purposively recruited 13 county hospitals into the CIN.8–11 The CIN has successfully fostered the implementation of standardised paediatric admission records (PAR) and creation of high-quality routine data on hospitals’ paediatric admissions.12,13 These data also allow us to assess how guideline-adherent care is, if there are specific challenges in guideline adherence and factors associated with reduced adherence. In this study we therefore aimed to address the following questions:

1. Which clinicians and how many are responsible for admission care in hospitals offering internship training in Kenya, and how many patients do they admit?
2. What proportion of patients are managed exactly in accordance with the key initial steps outlined in Kenyan clinical protocols?
3. Among children admitted by internship clinicians do factors such as clinician cadre influence adherence to guideline recommendations?

METHODS

Admissions database

Children are admitted to the hospitals in CIN by the duty clinician who completes a structured paediatric admission record (PAR)13 capturing patient demographics, presenting symptoms and clinical signs and admission diagnoses; additional charts help identify diagnostic tests ordered and prescribed treatment. Upon discharge or death, a trained data clerk retrospectively abstracts these data, discharge diagnoses and outcome into a customised electronic data capture tool (Research Electronic Data Capture).14 A full description of the data collection procedures including training, periodic refresher courses for clerks, daily local monitoring of data quality, centralised data quality monitoring and the process of web-based data synchronisation is provided elsewhere.10

Clinician database

Since November 2015, the data clerks have also recorded basic details on all clinicians responsible for paediatric admissions. Data are recorded in a secure separate log and accompanying database. Each clinician is assigned a unique identifier linked to their gender, cadre (MO, CO), whether they were interns (MOI, COI) and their rotation start date (for MOI and COI). At the point of reviewing a patient’s file on discharge, the clerk identifies the admitting clinician and links the patient record to the clinician’s unique identifier.

Creating the cumulative correctness of Paediatric Admission Quality of Care score

The original PAQC score was designed to assess adherence to MoH Basic Paediatric Protocols for the three most common childhood admission diagnoses—malaria, pneumonia and diarrhoea with dehydration.17 It was based on three discrete domains (assessment, diagnosis/severity classification and treatment) that were allocated scores independently prior to summation. This scoring approach was amended for use in the current study for four reasons. First, the original score predated revised Kenyan and WHO pneumonia guidelines.18 Second, the improved routine data available from CIN meant that in the assessment domain the original 3-point score (0/1/2) could be simplified to a 2-point scale (0/1 representing complete/incomplete documentation of assessment) to minimise redundancy. Third, the data captured on the PAR also allowed us to derive from the data a ‘correct syndromic diagnosis’ according to the Kenyan protocols. This meant we could compare the clinician’s classification/diagnosis with what the protocol indicated was correct (and score classification correctness 0/1).

Lastly, we revised the scoring approach so that it reflected whether the clinicians’ practice was perfectly adherent across the sequence of correct assessment, classification, treatment choice (for disease and classification) and treatment dose after excluding patient groups with different treatment needs (as
Figure 1  Study population. Success with patient–clinician record linkage varied across hospitals. For instance, in eight hospitals, over 90% of all patients were linked while in the remaining five hospitals linked patients ranged from 52.5% to 86.6%. Malaria was more common among patients not linked reflecting lower success at record linkage in hospitals in settings of high malaria endemicity. CIN, Clinical Information Network; cPAQC, correctness of Paediatric Admission Quality of Care; HCW, healthcare worker.

shown in online supplementary file 4). This means one can only get a correct score in a later step of this sequence if all of the previous steps are also correct. These revisions (outlined in online supplementary file 1) resulted in the creation of the correctness of Paediatric Admission Quality of Care (cPAQC) score on a 5-point scale (0–4) with a maximum score representing perfect correctness and other scores representing the point in the sequence of steps where a clinician deviated from perfect adherence. For patients with multimorbidities, we used an all-or-none combination of disease-specific step scores as in the original PAQC score.7 This means if a patient has malaria and pneumonia they must perfectly adhere to both protocols, each in sequence, to get a maximum score.

For subsequent exploratory modelling we reviewed the cPAQC scores and identified that the largest drop in performance occurred at the severity classification stage and so considered a cPAQC score ≥2 to represent guideline-adherent care and a score of ≤1 to represent non-adherent care.

Statistical analyses
We use descriptive statistics for patient and clinician characteristics reporting these as frequencies (%) and median and IQRs as appropriate. To explore whether clinician-level factors including cadre and whether the early or late phase of a clinician’s internship affect the quality of care (guideline-adherent vs non-adherent care) we used Bayesian hierarchical models using Stan17 and the Hamiltonian Monte Carlo approach which has advantages in fitting complex models18 (see online supplementary file 2 for details including findings of a sensitivity analysis). Significance of ORs was assumed if 95% credible intervals excluded one. All analyses were performed using R V.3.4.3 (R Foundation for Statistical Computing, Vienna, Austria; http://www.cran.r-project.org).

RESULTS
Data linkage
The full study cohort included 60051 patients admitted to paediatric wards of the participating hospitals and a total of 2371 clinicians (figure 1). Linking the two databases (patient and clinician) was not possible for a total of 7048 patients and 881 clinicians (figure 1). Consequently, only 53003 patients linked to 1489 clinicians of various cadres were eligible for further analyses; 2052 (3.88%) patients were admitted in the strike year (figure 1).
Table 1 Distribution of patient characteristics across groups

| Patient characteristics | Linked (n=53 003) | Not linked (n=70 484) |
|-------------------------|-------------------|-----------------------|
| Mortality               | 3199 (6.03%)      | 449 (6.42%)           |
| Age (months), median (IQR) | 17 (7–42)       | 24 (10–57)            |
| Gender (female)         | 23 547 (44.59%)  | 3078 (44.17%)         |
| Weight (kg), median (IQR) | 9 (6–14)        | 10 (8–16)             |
| Fever                   | 31 096 (72.48%)  | 4025 (75.15%)         |
| Unresponsive on AVPU scale | 457 (1.08%)     | 57 (1.08%)            |
| Malaria                 | 10 831 (20.43%)  | 2285 (32.42%)         |
| Pneumonia               | 20 267 (38.24%)  | 2084 (29.57%)         |
| Dehydration             | 9412 (17.76%)    | 1181 (16.76%)         |
| One comorbidity         | 29 738 (81.67%)  | 3874 (77.31%)         |
| Two comorbidities       | 6359 (17.46%)    | 1073 (22.41%)         |
| Three comorbidities     | 314 (0.86%)      | 64 (1.28%)            |

AVPU, alert verbal pain unresponsive.

Characteristics of study population

Out of the eligible population (n=53 003), there were 23 547 (44.59%) females, median age was 17 (IQR 7–42) months and 31 99 (6.03%) patients died. Pneumonia was the single most common admission diagnosis. Patient characteristics were not appreciably different between linked and unlinked patients (table 1).

Workload of the admitting clinicians

In the 25-month non-strike period there were 14 899 clinicians who were successfully linked to the eligible patient population, 869 (58.30%) clinicians were male and COI and MOI comprised the largest groups, with median (range) numbers per hospital of 52 (5–160) COIs and 28 (11–68) MOIs over this period. Far fewer fully registered practitioners were involved in admitting children (table 2) although patterns for which cadre was responsible for admitting most children varied quite substantially across hospitals (figure 2). The MOI group admitted the greatest number of children closely followed by the COI group (46.1% and 40.9% of all linked cases respectively (see table 2 and figure 2)). There was a considerable decrease in the number of patients clinicians admitted during the strike year (table 2).

Quality of care at admission

To explore quality of care, we analysed data from 22 641 eligible patients using the cPAQC score (figure 1). We present illustrative results for MOI who admitted the most patients (n=10 115). We note a substantial drop in the cPAQC score at the point of severity classification for each disease. This indicates that while clinicians typically document a full patient assessment their classification is then often not correct as judged by the Kenyan protocols (see figure 3). For pneumonia where correct classification is more common there is a further marked decline in cPAQC score because the treatment prescribed is not correctly aligned with the disease classification that the recorded clinical signs and agreed protocol recommend. The end result is that perfect, sequential adherence to protocols is found in 12% or less of children admitted with malaria, pneumonia or diarrhoea with dehydration. Similar cascades for 9891 children admitted by COI, 1617 children admitted by MO and 1018 children admitted by CO were similar to those presented for MOI (online supplementary file 3).

While perfect adherence to Kenyan protocols was relatively poor additional analyses indicated that among children with pneumonia 74.4% (6636/8921) were prescribed one of the two recommended first-line treatments (amoxicillin or penicillin with gentamicin) overall and when these drugs were prescribed in 84.5% (5605/6636) cases doses were correct. Similarly, 82.9% (4882/5888) children with malaria and 66.1% (1912/2893) with diarrhoea with dehydration received a recommended first-line treatment for their disease (artemether-lumefantrine/artsunate or oral/intravenous fluids, respectively) and these prescriptions were of the correct dose in 57.9% (2826/4882) and 66.3% (1267/1912) prescriptions, respectively.

Factors influencing guideline-adherent care at admission

We used data on 19 072 patients admitted by MOI or COI to explore factors associated with guideline-adherent care (table 3, with similar findings in our sensitivity analysis in online supplementary file 2). Patients with multimorbidity had significantly lower guideline adherence; two comorbidities (adjusted OR (AOR) 0.12 (95% CI 0.10 to 0.14)), three comorbidities (AOR 0.02 (95% CI 0.01 to 0.05)). Clinical data indicating the presence of any severe disease classification were associated with better guideline adherence (AOR 1.82 (95% CI 1.68 to 1.96)). MOI provided more guideline-adherent care compared with COI (AOR 1.19 (95% CI 1.07 to 1.34)) and care provided by clinicians in the later part of their rotation was marginally more likely to be guideline adherent (AOR 1.09 (95% CI 1.02 to 1.18)). Neither the child’s nor the clinician’s gender had an effect on guideline adherence, but younger patients aged 1–11 months were more likely to receive guideline-adherent care (AOR 1.21 (95% CI 1.13 to 1.30)).

DISCUSSION

In data from 13 county hospitals that train physician and non-physician clinician interns in Kenya, 1489 clinicians could be linked to 53 003 admissions over a period of 3 years including a period spanning major strikes. These interns rather than fully licensed clinicians admit 85% children. Each MOI admitted approximately twice as many patients as a COI during typical

Table 2 Comparison of patient admission workload for different cadres and between the strike year and a period without healthcare workers’ strikes

| Clinician cadre | Patients admitted during non-strike year (December 2016 to November 2017) | Patients admitted during strike year (December 2016 to November 2017) |
|-----------------|--------------------------|--------------------------|
|                 | Median number of clinicians per cadre (IQR) | Median number of patients per each clinician (IQR) | Median number of clinicians per cadre (IQR) | Median number of patients per each clinician (IQR) |
| Clinical officer | 5.1 (2–10)               | 6 (3–24)                 | 7.1 (4–30)               | 9 (6–42)                 |
| CO intern       | 46 (41–86)               | 1328 (995–1579)          | 13 (4–29)               | 15 (9–30)               |
| MO intern       | 22 (27–34)               | 1436 (999–1660)          | 20 (9–78)               | 107 (7–13)              |

CO, clinical officer; IQR, interquartile range; MO, medical officer.

Ogero M, et al. Arch Dis Child 2020;105:648–654. doi:10.1136/archdischild-2019-317256 651
Figure 2  Patients admitted by clinicians of various cadres across hospitals. Hospitals are arranged from left to right in the descending order according to the proportion of patients admitted by medical officer interns (MOI). Red and blue bars without values represent cadres whose admissions were <4% in a given hospital. CO, clinical officer; MO, medical officer.

3 months’ rotations. Reasons for this difference may be because COIs are typically unpaid and therefore may not work at nights or weekends, or because MOIs may have higher status and so they are preferentially given or take this work linked to the expectation that COs’ ultimate work is predominantly in ambulatory care.

Our data indicate that in the CIN hospitals there is a culture of good documentation of clinical symptoms and signs by interns (figure 3 and online supplementary material file 3), we believe inculcated and reinforced by senior clinical staff.19 20 We explored using a strictly defined, sequential score (the cPAQC score) at which steps in the process of care guideline adherence performance declines. We observed that clinicians commonly do not classify the severity of illness in accordance with guidance. Most often clinicians appear to overdiagnose severe illness. Potential explanations are that clinicians may follow a gut feeling about illness severity,21 although those studied had limited prior experience, or that they are risk averse and inclined to justify prescription of more aggressive treatment, an idea supported by prior work examining treatment allocation for pneumonia.22 A heightened concern for risk might perhaps explain the association of poor adherence with multimorbidity.23 24 Overtreatment as a result of overdiagnosing may be both wasteful and potentially could cause harm, for example, overuse of intravenous fluids in settings with poor inpatient monitoring.25

Among those admitted by internship clinicians our data suggest no effect of clinician gender on adherence to guidelines in keeping with other studies.26 27 There may be a small effect of cadre, with MOI more adherent than COI, and a marginal effect of learning during the interns’ 3 months’ rotation.26 28 The relatively weak effect of time period on guideline adherence may be because this is too short a period in which to observe individual

Figure 3  Performance of items constituting the correctness of Paediatric Admission Quality of Care (cPAQC) score for patients with diarrhoeal dehydration, malaria and pneumonia as assessed for medical officer interns (MOI). The cPAQC score spans four items of a care cascade such that correct performance of steps later in the pathway is only possible if earlier steps are also correct (represented as progression from left to right on the X-axis where axis labels also represent progression of the cPAQC score from 1 to 4). Performance is represented as the percentage of the 10115 patients (admitted by MOI) who achieved cPAQC scores for the respective diagnoses of 1, 2, 3 or 4.
We present what we believe is the first study to report how much documentation practices are now good (the first step in our care cascade) classification of the level of severity of illness frequently deviates from guideline recommendations. At present there is little evidence that non-adherence is corrected during clinicians’ internships raising questions about their supervision. More encouraging is the observation that the majority of children are at least prescribed correctly one of the recommended first-line treatment strategies for pneumonia, malaria and diarrhoea with dehydration. However, as the most common deviation from guidelines is overdiagnosis of severe illness it is possible that resources are being wasted and that children may spend more time in hospital receiving treatments that might cause harm or discomfort (eg, intravenous drugs). Further studies should explore the reasons for non-compliance, the possible consequences of overuse of treatments and whether de-escalating treatment is beneficial or harmful.

Table 3  Results of multivariable model showing the degree to which clinician and patient factors (represented by adjusted odds ratios and 95% CI) are associated with a CPAQC score of ≥2 used as an indicator for more guideline-adherent care (n=19072)

| Covariate                     | AOR  | 95% credible intervals |
|-------------------------------|------|------------------------|
| Comorbidities                 |      |                        |
| One                           | Ref  |                        |
| Two                           | 0.12 | 0.10 to 0.14*          |
| Three                         | 0.02 | 0.01 to 0.05*          |
| Clinician cadre               |      |                        |
| COI                           | Ref  |                        |
| MOI                           | 1.19 | 1.07 to 1.34*          |
| Practice period               |      |                        |
| Early                         | Ref  |                        |
| Late                          | 1.09 | 1.02 to 1.18*          |
| Illness severity classification|      |                        |
| Non-severe                    | Ref  |                        |
| Severe                        | 1.82 | 1.68 to 1.96*          |
| Clinician gender              |      |                        |
| Male                          | Ref  |                        |
| Female                        | 1.02 | 0.92 to 1.13           |
| Child sex                     |      |                        |
| Female                        | Ref  |                        |
| Male                          | 1.01 | 0.95 to 1.09           |
| Child age (months)            |      |                        |
| 1–11                          | Ref  |                        |
| 12–59                         | 1.21 | 1.13 to 1.30*          |

*Denotes a statistically significant relationship where <1 means less guideline adherent and >1 means more guideline adherent.

AOR, adjusted odds ratio; COI, clinical officer intern; CPAQC, correctness of Paediatric Admission Quality of Care; MOI, medical officer intern.

Learning, although it is notable that these interns adopted good documentation practices early in their internship. More probably it may be that those providing immediate supervision (typically MOs) may also not fully adhere to guidelines (as our data suggest) while supervision from paediatricians is limited.

Limitations

This study had a number of limitations. All hospitals were public hospitals but there were still variations in patterns of staffing and workloads. We focus only on immediate admission care and rely on the documentation in the medical files to assess adherence and thus assume that lack of documentation equates to non-adherent care. We are therefore unable to capture any nuances in the clinical condition that might better explain admission treatment decisions. We also assume that these admitting clinicians should strictly follow the national guidelines and that any deviation from this is incorrect. Perfect adherence to admission guidelines represents only one technical aspect of much wider issues in quality care that our analyses cannot address. Lastly, clinician–patient record linkage was not 100%. That said, we believe that studying a large population across multiple settings over a period of 3 years provides some useful insights into who provides routine patient care and where clinicians appear to deviate most from recommendations.

CONCLUSION

We present what we believe is the first study to report how much admission care is provided by junior, preregistered clinicians during their 3 months’ internship in an important group of Kenyan hospitals. While documentation practices are now good (the first step in our care cascade) classification of the level of severity of illness frequently deviates from guideline recommendations. At present there is little evidence that non-adherence is corrected during clinicians’ internships raising questions about their supervision. More encouraging is the observation that the majority of children are at least prescribed correctly one of the recommended first-line treatment strategies for pneumonia, malaria and diarrhoea with dehydration. However, as the most common deviation from guidelines is overdiagnosis of severe illness it is possible that resources are being wasted and that children may spend more time in hospital receiving treatments that might cause harm or discomfort (e.g., intravenous drugs). Further studies should explore the reasons for non-compliance, the possible consequences of overuse of treatments and whether de-escalating treatment is beneficial or harmful.

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**Figure 1: Logic used for Malaria patients**

**Primary Assessment**

**Malaria Inclusion Criteria**
- History of fever

**Diagnosis Classification**
- One of the danger signs: AVPU<A, Can’t drink, Respiratory distress (indrawing or grunting) with (severe pallor/Hb<5g/dl or Acidotic breathing)
- All of the following: AVPU = A, Able to drink, Normal Breathing (no grunting, no indrawing)

**Severe**
- Severe Malaria treatment
  - Drug = Quinine or Artesunate
  - Quinine
    - Loading dosage = 20mg/kg ±20% (≥ 16 & ≤ 24),
    - Maintenance dosage = 10mg/kg ±20% (≥ 8 & ≤ 12)
    - Route = IV or IM
  - Artesunate
    - Dosage = 2.4-3mg/kg ±20% (≥ 1.92 & ≤ 3.6)
    - Route = IV or IM

**Non-Severe**
- Non-Severe Malaria treatment
  - Drug = Coartem
  - Dosage
    - 0.5 tablet if <5kg
    - 1 tablet if ≥ 5 - <15kg
    - 2 tablets if ≥ 15 - <24kg
    - 3 tablets if ≥ 24 - ≤34kg

Exclude Vomiting everything
Figure 2: Logic used for Pneumonia patients

Pneumonia

Inclusion Criteria
- History of Cough
- Difficulty breathing

Primary Assessment
- Pediatrics at admission

Diagnosis
- One of the danger signs:
  - Oxygen saturation < 90%
  - Cyanosis
  - Grunting
  - AVPU=A, Can’t drink

Classification
- Severe
- Non-Severe

Exclude
- Age < 2m, Age > 59m, Readmission
- Admission diagnosis of meningitis, TB, severe malnutrition, HIV positive at admission

Severe Pneumonia treatment
- Drug = Gentamicin & Penicillin
- Dosage: 50000 IU/kg (Penicillin) ± 20% (40000 & 60000), 7.5mg/kg (Gentamicin) ± 20% (6 & 9)

Non-Severe Pneumonia treatment
- Drug = Amoxicillin
- Dosage: 40-45 ± 20% (32 & 54)

Any of the following:
- Indrawing
- Respiratory rate ≥ 40 bpm in
  - 12-59m old
- Respiratory rate ≥ 50 bpm in
  - 2-11m old

Exclude
- Vomiting Everything
Figure 3: Logic used for diarrhea/dehydration patients

Diarrhea-Dehydration

Inclusion Criteria

History of Diarrhea
or Vomiting

Primary Assessment

Pediatrics at admission

Diagnosis Classification

Shock treatment

Drug= Ringers (Hartmann's)/Normal saline

Bolus Dosage= 20 ml/kg ±20%
(16 & ± 24)

Step 1

Drug= Ringers (Hartmann's)/Normal saline

Step 2

Drug= Ringers (Hartmann's)/Normal saline

Step 2 Dosage= 70 ml/kg ±20%
(56 & ± 94)
Duration= 2.5 hrs in ≤12m old or 5 hrs in ≤12m old

Severe dehydration no shock

(Plan C)

Drug= ORS

Doseage= 100 ml/kg ±20%
(80 & ± 144)
Duration= 3 Hrs

Some dehydration treatment

(Plan B)

Drug= ORS

Doseage= 70 ml/kg ±20%
(56 & ± 94)
Duration= 4 Hrs

No dehydration treatment

(Plan A)

Drug= ORS

Doseage= 10 ml/kg ±20%
(8 & ± 12)

Exclude

Vomiting everything

Exclude

Age <1 month >59 months
Severe malnutrition,
Diarrhea 2-14 days,
Bloody diarrhoea

Exclude

Weak pulse, AVPU<A
Cold hands, Cap refill>3 sec
Sunken eyes
Slow skin pinch

All of the following

(Can't drink or AVPU<A)
Skin pinch ≥2 sec
Sunken eyes

Any of the following

Only Sunken eyes
Only Skin pinch ≥2 sec

Some dehydration

Slow skin pinch

No dehydration

Pediatrics at admission

Diarrhea-Dehydration

Inclusion Criteria

History of Diarrhea
or Vomiting

Primary Assessment

Pediatrics at admission

Diagnosis Classification

Shock treatment

Drug= Ringers (Hartmann's)/Normal saline

Bolus Dosage= 20 ml/kg ±20%
(16 & ± 24)

Step 1

Drug= Ringers (Hartmann's)/Normal saline

Step 2

Drug= Ringers (Hartmann's)/Normal saline

Step 2 Dosage= 70 ml/kg ±20%
(56 & ± 94)
Duration= 2.5 hrs in ≤12m old or 5 hrs in ≤12m old

Severe dehydration no shock

(Plan C)

Drug= ORS

Doseage= 100 ml/kg ±20%
(80 & ± 144)
Duration= 3 Hrs

Some dehydration treatment

(Plan B)

Drug= ORS

Doseage= 70 ml/kg ±20%
(56 & ± 94)
Duration= 4 Hrs

No dehydration treatment

(Plan A)

Drug= ORS

Doseage= 10 ml/kg ±20%
(8 & ± 12)
### Appendix Table 1: Malaria Cumulative Correctness of Pediatric Admission Quality of Care (cPAQC) score allocation table

| Domain                  | Domain details       | Clinical task                          | Scoring criteria                                                                 |
|-------------------------|----------------------|----------------------------------------|----------------------------------------------------------------------------------|
| Primary assessment      | Fever documentation  | Assess fever and document              | Score 1 if all items in Primary & secondary domains are documented                |
| Secondary assessment    | Convulsions          | Assess all signs and document          |                                                                                  |
|                         | documentation        |                                        |                                                                                  |
|                         | Acidotic breathing   |                                        |                                                                                  |
|                         | documentation        |                                        |                                                                                  |
|                         | Ability to drink     |                                        |                                                                                  |
|                         | documentation        |                                        |                                                                                  |
|                         | AVPU documentation   |                                        |                                                                                  |
|                         | Pallor documentation |                                        |                                                                                  |
|                         | Grunting documentation |                                    |                                                                                  |
|                         | Indrawing documentation |                                |                                                                                  |
| Complete assessment     | Primary & secondary  | Complete documentation of primary and  | Score 1 if there is a complete assessment of signs and malaria severity classification done according to guidelines |
|                         | assessment           | secondary signs of malaria             |                                                                                  |

### Diagnosis classification

**Severe malaria**

*Fever plus any of the following:*
- AVPU<A
- Inability to drink
- Respiratory distress with severe anemia
- Acidotic breathing

**Non-Severe malaria**

*Fever plus all of the following:*
- AVPU=A
- Can drink/breastfeed
- No grunting
- No indrawing

### Drug choice

**Severe malaria drugs**

- Artesunate or
- Quinine

**Non-severe malaria drug**

- Coartem
| Drug use/application | Severe malaria treatment | Apply malaria drugs appropriately (correct dosage and frequency) | Score 1 if preceding clinical tasks are done according to guidelines and drugs applied appropriately |
|---------------------|--------------------------|---------------------------------------------------------------|--------------------------------------------------------------------------------------------------|
|                     | **Dose: Quinine**        |                                                               |                                                                                                 |
|                     | *loading dose >=16 - 24mls/kg* |                                                               |                                                                                                 |
|                     | **Dose: Quinine**        |                                                               |                                                                                                 |
|                     | *maintenance dose >=8 - 12 mls/kg* |                                                               |                                                                                                 |
|                     | **Frequency: 8hourly**   |                                                               |                                                                                                 |
|                     | **Dose: Artesunate >=**  |                                                               |                                                                                                 |
|                     | 1.92 - 3.6mls/kg         |                                                               |                                                                                                 |
|                     | **Non-severe malaria treatment** |                                                               |                                                                                                 |
|                     | **Dose:**                |                                                               |                                                                                                 |
|                     | 0.5 tablet of coartem    |                                                               |                                                                                                 |
|                     | for <5kgs                |                                                               |                                                                                                 |
|                     | 1 tablet of coartem      |                                                               |                                                                                                 |
|                     | for 5-15kgs              |                                                               |                                                                                                 |
|                     | 2 tablets of coartem     |                                                               |                                                                                                 |
|                     | for 15-24kgs             |                                                               |                                                                                                 |
|                     | 3 tablets of coartem     |                                                               |                                                                                                 |
|                     | for 24-34 kgs            |                                                               |                                                                                                 |
|                     | **Maximum Malaria cPAQC Score=4** |                                                               |                                                                                                 |
### Appendix Table 2: Pneumonia Cumulative Correctness of Pediatric Admission Quality of Care (cPAQC) score allocation table

| Domain                   | Domain details                  | Clinical task                                                                 | Scoring criteria                                                                 |
|--------------------------|--------------------------------|------------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| Primary assessment       | Cough OR difficult breathing   | Assessment and documentation of cough or difficult breathing                  | Score 1 if all items in Primary & secondary domains are documented               |
| Secondary assessment     | Cyanosis                       | Assess all signs and document                                                 |                                                                                  |
|                          | Ability to drink               |                                                                               |                                                                                  |
|                          | AVPU                           |                                                                               |                                                                                  |
|                          | Respiratory rate               |                                                                               |                                                                                  |
|                          | Grunting                       |                                                                               |                                                                                  |
|                          | Indrawing                      |                                                                               |                                                                                  |
| Complete assessment      | Primary & secondary assessment | Complete documentation of primary and secondary signs of pneumonia            |                                                                                  |
| Diagnosis classification | Severe Pneumonia               | Use clinical signs to classify pneumonia severity levels accordingly          | Score 1 if there is a complete assessment of signs and pneumonia severity classification done according to guidelines |
|                          | Cough or difficult breathing   |                                                                               |                                                                                  |
|                          | plus any of the following:     |                                                                               |                                                                                  |
|                          | Oxygen saturation < 90%        |                                                                               |                                                                                  |
|                          | Cyanosis                       |                                                                               |                                                                                  |
|                          | Grunting                       |                                                                               |                                                                                  |
|                          | Grunting                       |                                                                               |                                                                                  |
|                          | AVPU < A                       |                                                                               |                                                                                  |
|                          | Inability to drink             |                                                                               |                                                                                  |
|                          | Non-Severe Pneumonia           |                                                                               |                                                                                  |
|                          | Cough or difficult breathing   |                                                                               |                                                                                  |
|                          | plus any of the following:     |                                                                               |                                                                                  |
|                          | Indrawing                      |                                                                               |                                                                                  |
|                          | Respiratory rate >=40          |                                                                               |                                                                                  |
|                          | in 12-59 months                |                                                                               |                                                                                  |
|                          | or Respiratory rate >=50       |                                                                               |                                                                                  |
|                          | in 2-11 Months                 |                                                                               |                                                                                  |
| Drug choice              | Severe pneumonia drugs         | Pneumonia drug prescriptions                                                  | Score 1 if preceding clinical tasks and drug(s) are prescribed according to guidelines |
|                          | Penicillin and                 |                                                                               |                                                                                  |
|                          | Gentamicin                     |                                                                               |                                                                                  |
| Drug use/application | **Non-severe pneumonia drug** | **Severe pneumonia treatment** | **Score 1 if preceding clinical tasks are done according to guidelines and drugs applied appropriately** |
|----------------------|-------------------------------|-------------------------------|---------------------------------------------------------------------------------------------------|
|                      | **Amoxil**                    | Apply pneumonia drugs         |                                                                                                   |
|                      |                               | appropriately (correct dosage, frequency and route)                                               |                                                                                                   |
|                      | **Dose: Penicillin >= 40000-60000 IU/kg** | **Dose: Gentamicin >= 6-9 MU/kg** |                                                                                                   |
|                      | Route: IV or IM               | Route: IV or IM               |                                                                                                   |
|                      | **Non-severe pneumonia treatment** | **Dose: Amoxil >= 32-54 mg/kg** |                                                                                                   |
|                      |                               |                               | Maximum Pneumonia cPAQC Score=4                                                                  |
### Appendix Table 3: Dehydration Cumulative Correctness of Pediatric Admission Quality of Care (cPAQC) score allocation table

| Dehydration | Domain | Domain details | Clinical task | Scoring criteria |
|-------------|--------|----------------|---------------|-----------------|
| Primary assessment | History of diarrhea OR Vomits | Assessment and documentation of history of diarrhea or vomits | Score 1 if all items in Primary & secondary domains are documented |
| Secondary assessment | Capillary refill | Assess all signs and document | |
| | Temperature gradient | | |
| | Sunken eyes | | |
| | Skin pinch | | |
| | Ability to drink | | |
| | AVPU | | |
| Complete assessment | Primary & secondary assessment | Complete documentation of primary and secondary signs of illness | |
| Diagnosis classification | Severe dehydration | Use clinical signs to classify dehydration severity levels accordingly | Score 1 if there is a complete assessment of signs and pneumonia severity classification done according to guidelines |
| | History of diarrhea OR Vomits plus all of the following: Inability to drink OR AVPU < A | | |
| | Skin pinch >=2 seconds | | |
| | Sunken eyes | | |
| | Some dehydration no shock | | |
| | History of diarrhea OR Vomits plus all of the following: Can drink/breastfeed | | |
| | Sunken eyes | | |
| | Skin pinch 1-2 seconds | | |
| | No dehydration | | |
| | History of diarrhea OR Vomits plus any of the following: Sunken eyes AND Skin pinch is immediate | | |
| | Skin pinch 1-2 seconds | | |
| Drug choice | Severe dehydration drug | | |
| Drug use/application | Severe dehydration treatment | Dehydration drug prescriptions | Score 1 if preceding clinical tasks and drug(s) are prescribed according to guidelines |
|----------------------|-----------------------------|-------------------------------|----------------------------------------------------------------------------------|
|                      | Drug= Ringers(Hartman’s)/Normal saline |                  |                                                                                   |
|                      | Step 1 & 2                  | Apply dehydration drugs appropriately (correct dosage, frequency and duration) |                                                                                   |
|                      | Dosage= 100mls/kg ±20%      |                  |                                                                                   |
|                      | (≥80 & ≤120)                |                  |                                                                                   |
|                      | Duration= 3Hrs ≥ 12m old or 6Hrs ≤ 12m old |                  |                                                                                   |
|                      | OR                          |                  |                                                                                   |
|                      | Drug= ORS                   |                  |                                                                                   |
|                      | Dosage=120mls/kg ±20%       |                  |                                                                                   |
|                      | (≥96 & ≤ 144)               |                  |                                                                                   |
|                      | Duration=6hrs               |                  |                                                                                   |
|                      | Some dehydration treatment |                  |                                                                                   |
|                      | Dosage ORS: >=60 - <= 90   |                  |                                                                                   |
|                      | Duration: 4Hrs              |                  |                                                                                   |
|                      | No dehydration treatment   |                  |                                                                                   |
|                      | Dosage ORS: >= 8 - <= 12   |                  |                                                                                   |
| Maximum dehydration cPAQC Score=4 |                  |                  |                                                                                   |
Model specification and selection

We initially used hierarchical logistic regression models with a 3-level structure: admitted patients (level 1); admitting clinicians (level 2); and hospitals (level 3). Variables included in the models were: patient’s age; child sex; number of comorbidities (1, 2, 3); illness severity level (severe, non-severe); clinician cadre; clinician gender and internship practice period (early (first five weeks), late (last 7 weeks)). Since multicollinearity was not a concern and missing data in all these explanatory variables were ignorable (<1%), we proceeded to perform a complete case analysis. However, these models failed to converge due to complexity in estimation of likelihoods when using the R package, lme4.

To determine the optimal variance structure of the model, we explored a total of 4 a-priori likely models presented in Table 1. Each of these models had similar explanatory variables but with varying variance structure (random effect part).

Table 1: model selection

| Model name | Model Description |
|------------|-------------------|
| Model 1    | Model with only fixed effects. |
| Model 2    | Model 1 + hospitals as random effects. |
| Model 3    | Model 1 + clinicians as random effects. |
| Model 4    | Model 1 + nested random effects (different intercepts for each clinician within hospital) |

For all models, we specified 4 chains which is considered adequate, each with 2000 iterations, half of which were devoted to the warm-up (adjusting the behaviour of the sampler) and were automatically discarded before results were displayed. To promote good mixing Hamiltonian Monte Carlo (HMC) chains, as recommended, we used weakly informative priors. Moreover, these priors are not very sensitive, in that, reasonable changes in the prior do not produce noticeable changes in the posterior [1]. To assess model convergence, we performed Gelman-Rubin diagnostics[2] which includes visual inspection of
the model chains of the estimated parameters. On convergence, all four chains of the samples should intermingle well and look highly similar to one another [3].

We compared candidate models in Table 1 using the recommended approximated leave-one-out cross-validation [4, 5] and the result suggested that model 4 best fitted the data. The chosen model is an adjusted hierarchical logistic regression model which allowed for clustering of patients by clinicians nested within different hospitals. Convergence of this model shown in Figure 1 suggested that all 4 chains converged. Posterior predictive checks of the same model were done by graphically comparing the densities of the actual data and the data replicated from the models’ posterior distribution and the result (see Figure 2) suggested that these densities were almost identical. Therefore, we proceeded to make inference.

Sensitivity analysis

In order to examine the consistency of our model results, we replicated the above analysis to a data subset in which ≥90% patients could be linked to a specific clinician ID within each hospital.

**Sensitivity analysis. Estimates of the factors influencing guideline-adherence in care using data from hospitals with only >= 90% patient-clinician record linkage (n=13438)**

| Covariate           | AOR  | 95% Credible intervals |
|---------------------|------|------------------------|
| Comorbidities       |      |                        |
| One                 | ref  |                        |
| Two                 | 0.10 | 0.08-0.12*             |
| Three               | 0.02 | 0.01-0.08*             |
| Clinician Cadre     |      |                        |
| COI                 | ref  |                        |
| MOI                 | 1.19 | 1.05-1.35*             |
| Practice Period     |      |                        |
| Early               | ref  |                        |
| Late                | 1.12 | 1.01-1.24*             |
Illness Severity

| levels   | Non-severe | ref | Severe          | 2.01 | 1.84-2.20* |
|----------|------------|-----|-----------------|------|-----------|

Clinician Gender

|         | Male       | ref | Female          | 1.01 | 0.90-1.15 |

Child sex

|        | Female     | ref | Male            | 0.99 | 0.91-1.08 |
|--------|------------|-----|-----------------|------|-----------|
|        | 12-59 months | ref |                 |      |           |

Child age

|      | 1-11 months | 1.24 | 1.14-1.35* |

*denotes a statistically significant relationship where (<1 means less guideline adherent, > 1 more guideline adherent. AOR= Adjusted odds ratio
Figure 1: Trace plot of the chosen model. All four chains of the samples for each parameter look highly similar to one another an indicator of model convergence.
Figure 2: The plot of the posterior predictive density of the chosen model. $y$ is the density of the observed data $y_{rep}$ is replicated data from the model. Densities of the observed and the replicated data look identical—an indicator of good fit.
Reference

1. Gelman, A., D. Lee, and J. Guo, *Stan: A probabilistic programming language for Bayesian inference and optimization*. Journal of Educational and Behavioral Statistics, 2015. 40(5): p. 530-543.

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3. Gelman, A., et al., *Bayesian data analysis*. 1995: Chapman and Hall/CRC.

4. Vehtari, A., A. Gelman, and J. Gabry, *Efficient implementation of leave-one-out cross-validation and WAIC for evaluating fitted Bayesian models*. arXiv preprint arXiv:1507.04544, 2015.

5. Vehtari, A., A. Gelman, and J. Gabry, *Practical Bayesian model evaluation using leave-one-out cross-validation and WAIC*. Statistics and Computing, 2017. 27(5): p. 1413-1432.
Figure 1: Performance of items constituting the cPAQC score for malaria, pneumonia and diarrhoea / dehydration patients as assessed for Medical Officer (MO), Clinical Officer (CO), Clinical Officer intern (COI). The cPAQC score spans 4 items of a care cascade such that correct performance of steps later in the pathway is only possible if earlier steps are also correct (represented as progression from left to right on the X axis and equal to a cPAQC score of 1 to 4). Performance is represented as the percentage of the 22,641 patients who achieved scores for the respective diagnoses of 1, 2, 3 or 4.