Health system capacity to manage diabetic ketoacidosis in nine low-income and lower-middle income countries: A cross-sectional analysis of nationally representative survey data

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Summary

Background There has been increasing awareness about the importance of type 1 diabetes (T1D) globally. Diabetic ketoacidosis (DKA) is a life-threatening complication of T1D in low-income settings. Little is known about health system capacity to manage DKA in low- and lower-middle income countries (LLMICs). As such, we describe health system capacity to diagnose and manage DKA across nine LLMICs using data from Service Provision Assessments.

Methods In this cross-sectional study, we used data from Service Provision Assessment (SPA) surveys, which are part of the Demographic and Health Survey (DHS) Program. We defined an item set to diagnose and manage DKA in higher-level (tertiary or secondary) facilities, and a set to assess and refer patients presenting to lower-level (primary) facilities. We quantified each item's availability by service level in Bangladesh (Survey 1: May 22 2014–Jul 20 2014; Survey 2: Jul 2017–Oct 2017), the Democratic Republic of the Congo (DRC) (Oct 16 2017–Nov 24 2017 in Kinshasha; Aug 08 2018–Apr 20 2018 in rest of country), Haiti (Survey 1: Mar 05 2013–Jul 2013; Survey 2: Dec 16 2017–May 09 2018), Ethiopia (Feb 06 2014–Mar 09 2014), Malawi (Phase 1: Jun 11 2013–Aug 20 2013; Phase 2: Nov 13 2013–Feb 7 2014), Nepal (Phase 1: Apr 20 2015–Apr 25 2015; Phase 2: Jun 04 2015–Nov 05 2015), Senegal (Survey 1: Jan 2014–Oct 2014; Survey 2: Feb 09 2015–Nov 10 2015; Survey 3: Feb 2016–Nov 2016; Survey 4: Mar 13 2017–Dec 15 2017; Survey 5: Apr 15 2018–Dec 31 2018; Survey 6: Apr 15 2019–Feb 28 2020), Tanzania (Oct 20 2014–Feb 21 2015), and Afghanistan (Nov 1 2018–Jan 20 2019). Variation in secondary facilities' capacity and trends over time were also explored.

Findings We examined data from 2028 higher-level and 7534 lower-level facilities. Of these, 1874 higher-level and 6636 lower-level facilities' data were eligible for analysis. Availability of all item sets were low at higher-level facilities, where less than 50% had the minimal set of supplies, less than 20% had the full minimal set, and less than 15% had the ideal set needed to diagnose and manage DKA. Across countries in lower-level facilities, less than 14% had the minimal set of supplies and less than 9% the full set of supplies for diagnosis and transfer of DKA patients. No country had more than 20% of facilities with the minimal set of items needed to assess or manage DKA. Where data were available for more than one survey (Bangladesh, Senegal, and Haiti), changes in availability of the minimal set and ideal set of items did not exceed 15%. Tertiary facilities performed best in

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Haiti, Ethiopia, Malawi, Nepal, Senegal, Tanzania, and Afghanistan. Secondary facilities that were rural, public, and had fewer staff had lower capacity.

Interpretation Health system capacity to manage DKA was low across these nine LLMICs. Although efforts are underway to strengthen health systems, a specific focus on DKA management is still needed.

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Keywords: Type 1 diabetes; Ketoacidosis; Africa; Low-income countries; Lower-middle income countries; Health systems; Noncommunicable disease; Emergency care; Critical care

Research in context

Evidence before this study

To identify and summarize the evidence before this study, a formal literature search strategy (see Supplementary File) was developed and employed in PubMed to identify articles through August 20, 2021. The search terms used to identify relevant studies were related to the epidemiology, services, and assessments of capacity for diabetic ketoacidosis (DKA) in LLMICs. This search yielded 299 studies. Identified studies primarily discussed the clinical profile and prognosis of DKA cases in hospitals in LLMICs, and individual-level risk factors for development of DKA. None of these studies used the Demographic Health and Surveys Program's Service Provision Assessment (SPA) surveys to assess health system capacity in lower and lower-middle income countries to manage DKA.

Added value of this study

This study is the first to assess health system capacity to diagnose and manage DKA in LLMICs using SPA data from 8510 facilities across nine countries. Using clinical guidelines and expert input, we defined a minimal and ideal set of items needed in higher-level facilities to diagnose and manage DKA, and a minimal set of items needed in lower-level facilities to assess and refer patients. Using this framework, we found that higher-level facilities had low capacity to diagnose and manage DKA, and lower-level facilities had low capacity to provide initial care and refer patients to higher-level facilities. Critical items needed for DKA management such as insulin and glucometers had shockingly limited availability. Among secondary facilities, capacity was lower in rural, public facilities with lower staff numbers. In countries with data over time, we found no substantial progress in health system capacity.

Implications of all the available evidence

Health system capacity to manage DKA in LLMICs was incredibly low. As a result, DKA is likely inadequately diagnosed and managed, causing delays or misdiagnoses that can increase likelihood of complications and death. We highlight the need for increased investment in monitoring and evaluation of health system capacity to manage severe, chronic NCDs. More frequent, standardized health facility assessments that include emergency service data are needed and should utilize the minimal and ideal sets we have defined to guide measurement of capacity to manage DKA. Capacity-building in emergency and high-dependency care should also be prioritized.

Introduction

Type 1 diabetes (T1D) is one of the most common chronic autoimmune disorders and creates a lifelong dependency on exogenous insulin.[1] However, in low- and lower-middle-income countries (LLMICs), basic, essential supplies to manage this disease (such as insulin and glucose monitoring kits) are frequently unavailable or unaffordable.[2–4] Patients often must travel long distances at great expense to access both emergency and follow-up care, and rarely receive adequate education on how to effectively manage their disease.[4,5] These barriers to care have led to misdiagnosis, acute and chronic complications, and premature death.[1,5] As a result, it has been estimated that premature death rates for people living with T1D in low- and middle income countries (LMICs) are nine or more times higher than the premature death rates for people living with T1D in high-income countries.[5] Furthermore, if T1D care were scaled up to close this gap, it is estimated that 58% of the death from T1D that occurred in LMICs in 2017 could have been averted.[5]

Without prompt diagnosis and adequate management of T1D, life-threatening complications such as diabetic ketoacidosis (DKA) can result.[6] DKA is the most common acute hyperglycemic emergency and cause of mortality for those with T1D, resulting from insufficient or total lack of insulin, illness, or prolonged fasting.[6,7] DKA often is the initial presentation of T1D, especially in low-income settings with lack of access to insulin.[6,8] Although it is estimated that the rate of DKA is higher in LLMICs, its burden in LLMICs is largely unknown.[4,6,7] Evidence from single-center studies suggest that DKA in new-onset T1D is more common in LLMICs compared to upper and upper-middle income countries, with rates ranging from 62.2 to 77.1% in Nigeria, 69.8% in South Africa, and 92.1% in Sudan.[9–11] In comparison, in upper and upper-middle income countries in North America and Europe the rates range from 14.7% (Denmark) to 42.0% (France).[12]

Previous studies have used Service Provision Assessment (SPA) surveys in LLMICs to collect relevant information on non-communicable diseases (NCDs), primarily on items relevant for common conditions addressed through the World Health Organization's Package of Essential Noncommunicable Disease Interventions (WHO PEN).[13] These studies have found low health system capacity to diagnose and manage T1D and type two diabetes (T2D).[3,14–16] One such study reported that in public secondary facilities across eight LLMICs, insulin availability was as low as 1% in Bangladesh (2014), and blood glucose monitoring equipment as low as 9% in Senegal (2016–2017).[3] Despite this concerningly low capacity to diagnose and treat T1D, no studies have looked at the capacity to diagnose and treat DKA due to undiagnosed or unmanaged T1D.

Given this gap in the diabetes literature, we have analyzed the capacity of higher-level facilities across nine LLMICs to diagnose and manage DKA by evaluating the availability of items in four domains: (1) medications, (2) equipment, (3) diagnostic supplies, and (4) staff and guidelines. We also examined the capacity of lower-level facilities to assess and refer patients with suspected DKA and looked at how capacity to care for patients with DKA at higher-level facilities has changed over time.

Methods

Study setting and data sources

In this cross-sectional study, we used data from Service Provision Assessment (SPA) surveys, which are part of the Demographic and Health Survey (DHS) Program.[17] We included SPA surveys that provided nationally representative data on health facility capacity to address certain NCDs. These surveys collected data over a period of one to eight months and took place during one or two years. Sampling strategies varied – some countries conducted complete censuses of all facilities, while others conducted a complete census of some facility types and sampled of other types of facilities. A detailed description of the sampling strategies is described in the Appendix (Supplementary Table S1). Further details on survey design and instruments are available in each country's SPA online report.[18] We included survey data from Bangladesh (Survey 1: May 22 2014–Jul 20 2014; Survey 2: Jul 2017–Oct 2017), the Democratic Republic of the Congo (DRC) (Oct 16 2017–Nov 24 2017 in Kinshasha; Aug 08 2018–Apr 20 2018 in rest of country), Haiti (Survey 1: Mar 05 2013–Jul 2013; Survey 2: Dec 16 2017–May 09 2018), Ethiopia (Feb 06 2014–Mar 09 2014), Malawi (Phase 1: Jun 11 2013–Aug 20 2013; Phase 2: Nov 13 2013–Feb 7 2014), Nepal (Phase 1: Apr 20 2015–Apr 25 2015; Phase 2: Jun 04 2015–Nov 05 2015), Senegal (Survey 1: Jan 2014–Oct 2014; Survey 2: Feb 09 2015–Nov 10 2015; Survey 3: Feb 2016–Nov 2016; Survey 4: Mar 13 2017–Dec 15 2017; Survey 5: Apr 15 2018–Dec 31 2018; Survey 6: Apr 15 2019–Feb 28 2020), Tanzania (Oct 20 2014–Feb 21 2015), and Afghanistan (Nov 1 2018–Jan 20 2019). Data from all countries except Ethiopia were available publicly from the DHS Program website. We received Ethiopian data from the Ethiopian Public Health Institute. According to World Bank classifications for the 2020–2021 fiscal year, five of these countries were classified as lower-middle-income (Bangladesh, Haiti, Nepal, Senegal, and Tanzania) and four were classified as low-income (DRC, Ethiopia, Malawi, and Afghanistan).[19]

Study design and ethical statement

We followed the Strengthening the Reporting of Observational Studies in Epidemiology guidelines, given that our study is a secondary analysis of cross-sectional data.[20] All included data is open-access and accessed at the facility level. Therefore, there was no identifying information and was exempt from review by the Ethical Board and participant informed consent is not applicable to this study.

Data analysis

Our primary outcome was the capacity of higher-level facilities to diagnose and manage DKA. We defined capacity to diagnose and manage DKA as the availability of a minimal and ideal set of items that included four domains: (1) medication, equipment, (2) diagnostic tests, (3) staff, (4) and guidelines. As a secondary outcome, we assessed the capacity of lower-level facilities to assess and refer patients with suspected DKA. We constructed these item sets based on the second edition of the "Pocketbook for Management of Diabetes in Childhood and Adolescence in Under-Resourced Countries" developed by the Life for a Child Program (LFAC) and the International Society for Pediatric and Adolescent Diabetes (ISPAD), as well as clinical expert review.[1] Clinical justification for the use of these item sets is in the Supplementary Table S2. Table 1 shows the minimal and ideal set of items for higher-level facilities, and Table 2 shows the minimal set of items for lower-level facilities.

We considered medications to be available if the SPA interviewer observed them to be present and unexpired. Equipment and diagnostic consumables were considered available if they were observed to be present and

Domain	Item	Measured in SPA survey
Minimal set		
Medications	Insulin, disaggregated by type and method of injection	Partial: Disaggregation by type not available in most surveys[a] and by method in all surveys
	IV fluids: normal saline or ringer's lactate	Yes
	IV fluids: glucose containing fluids (dextrose - regardless of %)	Yes
	Potassium	No
	Oral rehydration salts (ORS)	Yes
Equipment	Glucometer: machine	Yes
	Age appropriate IV supplies: adult and pediatric	Yes
	Age appropriate blood pressure apparatus, digital and/or manual	Yes
	Insulin syringe	No
Diagnostic (consumables)	Ketones test (urine dipstick)	Yes[b]
	Glucometer: test strips	Yes
Staff and guidelines	Guidelines for diabetes diagnosis and treatment, including guidance on management of DKA	Partial: surveys do not report on guidance regarding DKA management specifically
	Presence of a health care worker trained in diabetes diagnosis and treatment	Yes
	24-h staff	Yes
Ideal set[c]		
Medications	Glucagon	No
	Mannitol	No
Equipment	Age-appropriate weight scale: adult and pediatric	Yes
	Thermometer	Yes
	IV pump	No
	Blood chemistry analyzer, in the facility	Yes
Diagnostics (consumables)	Blood chemistry analyzer reagents (creatinine, potassium, sodium, bicarbonate, chloride, glucose)	No

[a]Only the Malawi 2013-14 survey allowed for disaggregation of insulin type by survey. All other surveys collected information on the availability of insulin "lente" or the type was not specified. [b]The SPA question refers to "urine protein test" but does not specify urine ketone testing. Most urine protein dipstick tests also allow for testing of ketones. [c]The ideal set includes all items in the minimal set in addition to the items listed under this category.

Table 1: **Minimal and ideal set for diagnosis and management of diabetic ketoacidosis (DKA) in higher-level health care facilities.**

functional in the emergency services section in countries with available data (Afghanistan and Ethiopia), or in the NCD or general outpatient areas. We considered guidelines to be available if they were observed to be present by survey interviewers. Total staff availability was determined based on interviewee's report of their full-time assignment, employment, or secondment to the facility.

We cleaned, standardized, and merged each country's information into one dataset. Facilities were excluded from the primary analysis if survey weights indicated an incomplete survey (missing or zero) or if they did not provide inpatient services. In countries with multiple iterations of the SPA survey, we used the most recent survey for primary analysis. Given only 0–1% of data were missing after exclusion of incomplete surveys, missing values for items were considered not present at the facility unless the survey did not ask the question. The percentage of total facilities per country by facility type (tertiary, secondary, other, or unknown) with each item was tabulated using survey weights. We then calculated the percentage of facilities with the complete

Minimal set

Domain	Item	Measured in SPA survey
Medications	IV fluids: normal saline or ringer's lactate	Yes
Equipment	Glucometer: machine and test strips	Yes
	Age appropriate IV supplies: adult and pediatric	Yes
	Ambulance, on-site or nearby	Yes
Diagnostics (consumables)	Ketones test (urine dipstick)	No
	Glucometer: test strips	Yes
Staff and guidelines	24-h staff	Yes

Table 2: **Minimal set for assessment and referral of diabetic ketoacidosis in lower-level health care facilities.**

minimal set of supplies, full minimal set (including staff and guidelines), and ideal set.

To explore variation in secondary facilities' capacity to diagnose and treat DKA by subgroup, we built on previously used methods and conducted a multiple linear regression analysis.[14] We examined capacity by facility location, management authority, sources of revenue, routine user fees, staff, and the ratio of one staff member to ten inpatient beds (see details in Supplementary Table S3). To quantify facility capacity, a service readiness score for the minimal and ideal sets was constructed using guidance from the World Health Organization Service Availability and Readiness guidelines.[21] We calculated scores for the four domains representing their average availability of items, and then an overall score representing the average of these four scores (see details in Supplementary Tables S4 and S5). To explore the influence of capacity by facility characteristics, we pooled data across countries, ran separate regression models regression on the unweighted survey data for the minimal and ideal sets, and reported coefficients and 95% confidence intervals. We adjusted this analysis to use robust standard errors to account for potential clustering in the regression model Each subgroup level was run as an independent variable and adjusted for country effects. Separate models were run for each revenue source, facility staff type, and staff member to ten beds ratio. We did not run regression models with more than one subgroup given they are strongly related.

To analyze trends over time, we calculated the percent difference in each item's availability and the percentage of facilities with a complete minimal set of supplies alone, the full minimal set of items, and the ideal set of all items. The country surveys included were Bangladesh 2014–2017, Haiti 2014–2017–18, Senegal 2014–15 to 2016–17, and Senegal 2016–17 to 2018–19.

We conducted a sensitivity analysis using survey data from Afghanistan 2018–19 and Ethiopia 2014 that assessed emergency service areas. Certain items measured may be accessible only to the specific service area it is located in, so we extracted data on these items that may vary in accessibility and calculated the percentage of facilities with each item in the emergency services area and the outpatient/NCD service area. Then, we calculated the ratio and difference of these two numbers (Supplementary Table S14). To explore the effect of estimating availability using outpatient/NCD service area data, we applied item ratios, item differences, overall set ratios, and overall set differences from Ethiopian emergency service data to the outpatient/NCD service area estimates, disaggregated by higher-level facility service level. We assessed each item's influence on the overall set availability by increasing emergency service item availability to 100%. We ran an analysis to explore the difference in availability of glucose-containing fluids across countries by calculating each individual country's availability of every glucose-containing fluid.

Patient and public involvement
There was no involvement with patients or the public in the design, execution, or dissemination of this study.

Role of the funding source
The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. Authors SM and MC were responsible for cleaning and analyzing the dataset, which was accessible to all authors. All authors had final responsibility to submit this study for publication.

Results
Health facility characteristics
Using the nine countries' most recent SPA surveys, we initially examined data from 2028 higher-level and 7534 lower-level facilities. We identified 1874 higher-level and 6636 lower-level facilities that were eligible for the primary analysis (further details in Supplementary Tables S7 and S7).

Primary analysis
Higher-level facility readiness
Fig. 1 shows the percent of tertiary, secondary, other, and unknown higher-level facilities with all items in the minimal set of (1) supplies (2) the full minimal set of all items, and (3) the ideal set of all items. Availability of all item sets was low across countries, with large variability between countries. Minimal set availability sharply decreased by 6.8% to up to 33.8% across countries with the addition of staff and guidelines. Tertiary facilities performed best across countries (ranging from 6.8% to 48.1% availability, except in the DRC and Bangladesh. In all countries, less than 50% of higher-level facilities had the minimal set of supplies necessary to diagnose and manage DKA, less than 20% had the full minimal set of items, and less than 15% had the ideal set of items.

Table 3 shows the percent of higher-level facilities with each item available across countries, disaggregated by facility service level. Availability varied widely across items and countries. To explore which item influenced availability of the minimal set of supplies, the full minimal set of items, and the ideal set of items, we looked at which items had the lowest availability by country and facility service level (Supplementary Table S8). In the minimal set of supplies, the item with the lowest availability in tertiary and unknown facilities was age-appropriate IV supplies (tertiary range: 17%–66%; unknown range: 35%–75%). In secondary facilities, the item with the lowest availability was

Fig. 1: **Percent of higher-level facilities with complete minimal and ideal set, disaggregated by level and country.** This figure represents the percentage of higher-level facilities with the complete minimal set of supplies, complete full minimal set, and complete ideal set by country and facility type. Each individual country has its own separate graph with the bars representing the percentage of facilities with the complete set (with the percentage depicted above each bar) for the minimal set of supplies (first set of bars), the full minimal set (second set of bars), and the ideal set (third set of bars). Within each set, the facility type is depicted by color (green for tertiary, orange for secondary, and purple for unknown). The text below this figure should read "See Table 1 for definition of minimal and ideal set".

insulin (2%–92%), followed by the full glucometer set (17%–98%). We also looked at which items made the largest difference in overall set availability when availability was increased to 100% by country and facility service level (Supplementary Table S9). In contrast to the item with lowest availability, the item with the most influence on overall set availability in tertiary facilities when increased to 100% was the glucometer set. The item with the lowest availability in the full minimal set and ideal set across facility levels was trained staff, followed by insulin and T1D/T2D guidelines.

Secondary analyses

Lower-level facility service readiness

We analyzed the capacity of lower-level health care facilities to undertake an initial assessment of patients with suspected DKA and refer these patients to higher-level facilities after providing intravenous fluids. We calculated the availability of the minimal set of (1) supplies, (2) the availability of the minimal set of all items, and (3) the availability of each individual item (Fig. 2 and Table 4). Of the lower-level facilities, smaller health centers and clinics performed best in all countries (minimal set of supplies: 0.1%–13.6%; full minimal set: 0%–12.3%) except for the DRC, where the unique category of large health centers performed the best (minimal set of supplies: 9.5%; full minimal set: 9.2%). All countries except for Afghanistan–in which the survey was only conducted in private health centers - had less than ten percent of lower-level facilities with the minimal set of supplies or the full minimal set of all items. Dispensaries and health posts had the lowest availability of the minimal set of items across countries (minimal set of supplies: 0%–3.4%; full minimal set: 0%–2.3%). The item with the lowest availability across countries was a glucometer with test strips (0%–48%).

Percentage of higher-level facilities with item available, %

Set	Item	Bangladesh 2017			DRC 2017-18		Ethiopia 2014[b]		Haiti 2017-18			Malawi 2013-14			Nepal 2015			Senegal 2018-19	Tanzania 2015			Afghanistan 2018-19[b]
		T	S	O	T	S	T	S	T	S	O	T	S	O	T	S	O	UK	T	S	O	UK
		n=62	n=135	n=111	n=5	n=483	n=31	n=179	n=14	n=46	n=67	n=4	n=65	n=41	n=27	n=75	n=143	n=58	n=33	n=96	n=124	n=75
Minimal set	Insulin	13	2	35	20	55	90	75	57	46	46	100	46	61	31	12	50	48	85	92	71	63
	Normal saline or ringer's lactate	84	81	80	100	90	100	97	100	96	94	100	97	93	97	100	75	74	94	99	100	100
	IV glucose	85	80	80	100	88	97	92	100	96	94	100	100	98	100	97	74	74	94	97	98	99
	ORS	92	93	67	80	84	90	95	71	67	58	100	98	80	73	95	73	37	85	85	95	80
	Glucometer (full)[a]	29	37	60	40	78	68	28	71	76	61	100	60	71	17	17	24	63	67	70	85	38
	Glucometer[a]	32	44	60	60	87	NA	NA	79	80	64	100	75	78	17	19	24	63	76	83	86	50
	Glucometer strips[a]	29	37	62	40	79	NA	NA	86	78	64	100	65	71	17	17	24	70	67	71	85	40
	Age appropriate IV supplies[a,c]	23	18	31	40	52	55	54	50	52	51	25	65	76	17	33	42	35	66	59	59	75
	Adult[a,c]	26	21	34	40	49	74	65	50	54	52	75	83	93	20	37	51	38	81	71	70	NA
	Pediatric[a,c]	58	59	73	40	49	58	55	50	52	57	50	65	76	17	33	42	39	66	59	60	NA
	BP apparatus (either)[a,c]	98	100	100	100	98	100	95	100	100	99	100	85	90	93	97	96	96	100	86	98	94
	Manual[a,c]	98	100	100	100	91	94	93	86	96	90	75	65	78	93	97	94	84	94	77	89	94
	Digital[a,c]	5	4	20	20	26	29	18	50	48	42	100	62	83	3	3	16	91	43	32	47	33
	Urine protein test	61	37	68	60	58	97	96	71	85	61	75	58	83	82	93	82	90	91	88	87	83
	Guidelines	24	17	2	20	39	42	25	21	15	8	50	49	54	3	8	2	23	57	67	50	20
	National	19	15	1	20	26	19	10	7	7	2	50	35	39	NA	NA	NA	18	42	49	30	6
	Other	5	2	0	0	13	23	15	14	9	6	0	14	15	NA	NA	NA	5	15	18	20	14
	Trained staff	19	29	16	60	15	26	20	71	46	52	25	28	39	7	0	2	34	36	49	25	15
	24-hour staff	92	93	82	80	98	87	87	100	89	76	75	82	73	82	89	67	46	100	100	98	92
Ideal set	Age appropriate weight scale[a,c]	69	57	82	20	45	39	28	86	59	52	25	52	58	24	43	41	69	27	27	41	23
	Adult[a,c]	94	88	99	100	98	87	73	100	89	94	100	77	90	90	93	94	94	91	89	96	60
	Infant[a,c]	69	62	82	20	46	39	30	86	63	52	25	65	61	24	43	41	71	33	28	41	28
	Thermometer[a,c]	89	94	97	100	96	87	84	93	91	87	50	89	95	93	97	97	93	85	80	95	77
	Blood chemistry analyzer	40	19	73	100	27	94	63	64	52	57	100	32	53	79	39	72	67	76	75	64	88

T, Tertiary; S, Secondary; O, Other; UK, Unknown. [a]Results for Afghanistan 2018–19 and Ethiopia 2014 were sourced from the sections of the SPA that assessed emergency service areas. All other countries did not have this information available, and results reflect availability in the general outpatient area and/or the NCD service area. [b]Facilities were excluded if they did not provide services for medical emergencies or did not have an emergency service area, including facilities with only a pediatric emergency service area. [c]Ethiopia 2014 measured variable in both emergency services and pediatric emergency service areas. To count as present, item had to be available in one of these service areas.

Table 3: **Percent of all higher-level facilities with items available across countries, disaggregated by service level.**

Subgroup analysis

Five surveys (Bangladesh 2017, DRC 2017–18, Ethiopia 2014, Haiti 2017–18, and Tanzania 2014–15) were included in the regression analysis to explore the variation in the overall service readiness scores for the minimal and ideal sets by hospital characteristics in secondary facilities (Supplementary Tables S10–S12). The results of this analysis showed that the overall readiness score of facilities was significantly lower in rural versus urban facilities. We also found that readiness was significantly higher in secondary facilities in private versus public facilities, and in facilities receiving revenue from user payment into a fixed funding mechanism and/or pay per use funding mechanism. Higher numbers of generalists, specialists, nurses/midwives, pharmacists/pharmacy technicians, and/or lab technician were all significantly associated with higher readiness scores. Results did not differ in the readiness scores for the minimal set versus the ideal set.

Time trend analysis

Three countries (Bangladesh, Haiti, and Senegal) had multiple iterations of SPA survey data available. For these countries, we calculated the percentage point difference in item availability in higher-level facilities as compared with the prior survey. We also disaggregated by facility service level (Supplementary Table S13). In Haiti, item availability increased from 2013 to 2017–18 in tertiary facilities and decreased in facilities unable to be categorized (other). No change was viewed in Haitian secondary facilities. In Bangladesh, item availability decreased in tertiary, secondary, and unknown level facilities from 2014 to 2017. From 2016–17 to 2018–19, item availability in Senegal increased in unknown level facilities. However, changes in availability of the overall minimal set of items or the ideal set of items did not exceed 15%.

Sensitivity analysis

The sensitivity analysis comparing the ratio and difference estimates between emergency services and outpatient/NCD services in Afghanistan and Ethiopia showed that emergency service availability was higher or approximately the same for age appropriate IV supplies, blood pressure apparatus, 24-h staff, the minimal set of just supplies, full minimal set, and ideal set (Supplementary Table S14). After applying the Ethiopian availability ratio and difference between emergency and outpatient/NCD services for every item (Supplementary Tables S15 and S16, Supplementary Figs. 3, 4, 7, and 8) and for the minimal and ideal sets (Supplementary Figs. S5, S6, S9, and S10), both analyses resulted in an increase or no change in both

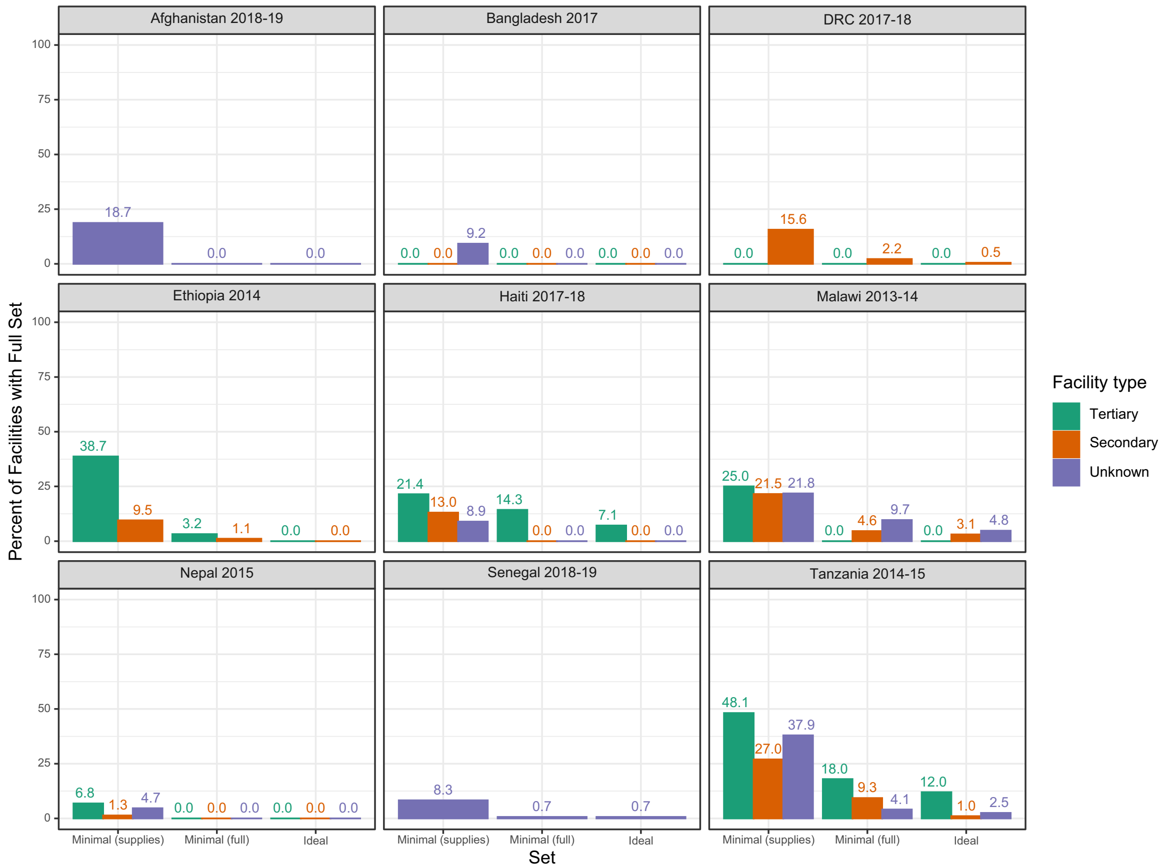

***Fig. 2:* Percent of lower-level facilities with complete minimal set, disaggregated by facility type and country.** This figure represents the percentage of lower-level facilities' with the complete minimal set of supplies and complete full minimal set by country and facility type. Each individual country has its own separate graph with the bars representing the percentage of facilities with the complete set (with the percentage depicted above each bar) for the minimal set of supplies (first set of bars) and the full minimal set (second set of bars). Within each set, the facility type is depicted by color (green for health centres and clinics, orange for large health centres, purple for health posts, and pink for dispensaries). The text below this figure should read "See Table 2 for definition of minimal set".

tertiary and secondary facilities' availability of the minimal set of supplies and full set, and a slight decrease or no change in the ideal set. When availability of emergency service items was increased to 100% of facilities, increase in set availability ranged from zero to 9.3% in tertiary facilities (excluding Malawi, who only had four), and from zero to 19.8% in secondary facilities.

Item	Percentage of lower-level facilities with item available, %																			
	Bangladesh 2017		DRC 2017-18		Ethiopia 2014		Haiti 2017-18		Malawi 2013-14			Nepal 2015			Senegal 2018-19	Tanzania 2015		Afghanistan 2018-19
	HC n=443	HP n=349	HC n=540	LHC n=352	HC n=481	HP n=470	HC n=524	DISP n=352	HC n=790	HP n=20	DISP n=47	HC n=245	HP n=311	DISP n=112	HC n=620	HC n=439	DISP n=493	HC n=48
Normal saline or ringer's lactate	4	14	72	83	84	5	75	65	78	24	74	78	90	84	71	91	84	92
Glucometer (full)	23	1	21	62	12	1	56	17	16	0	4	2	0	0	80	48	16	27
Machine	25	1	25	72	NA	NA	63	20	18	0	4	2	0	0	82	56	18	27
Test strips	28	1	22	63	NA	NA	58	17	16	0	4	2	0	0	83	48	17	28
Ambulance	7	4	15	32	80	67	24	18	70	40	77	64	52	53	68	65	54	90
On-site	1	0	1	6	12	0	11	2	19	5	11	13	3	0	40	27	3	81
Nearby	6	4	14	26	67	66	14	16	51	35	66	51	50	53	29	38	51	9
Age-appropriate IV supplies	0	0	53	59	25	1	41	36	50	10	40	22	25	21	13	36	28	42
Adult	0	1	60	62	41	4	48	47	70	20	66	45	55	52	13	51	46	NA
Pediatric	5	18	54	59	25	1	41	37	52	10	40	22	26	22	13	37	28	NA
Urine ketones test	9	8	13	44	60	0	49	15	9	0	0	34	3	0	69	60	20	88
24-hour staff	1	7	72	88	65	9	21	5	22	10	8	22	7	1	6	72	17	78

HC, Health centers and clinics; HP, Health posts; LHC, Large health centers; DISP, Dispensaries/Other; LHC, Large health centers.

***Table 4:* Percent of lower-level facilities with available items, disaggregated by facility type and country.**

With respect to glucose-containing fluids, all countries collected information on the availability of 5% dextrose and the item "glucose injectable solution" (Supplementary Table S17). The concentration of the glucose injectable solution was not specified in most countries except as "10% or 50%" in Ethiopia and Malawi, and "5%" in Nepal.

Discussion

We report the first study to date evaluating health system capacity to manage DKA in LLMICs. Our analysis revealed that across nine LLMICs, higher-level facilities had low availability of the supplies, trained staff, and guidelines needed to diagnose and manage DKA. Lower-level facilities lacked the capacity to provide initial care for suspected DKA and refer patients to a higher-level facility. Our subgroup analysis indicated that availability of the minimal and ideal sets needed to diagnose and manage DKA in secondary facilities were significantly lower in hospitals that are rural, public, or had lower staff numbers. Trends over time varied but showed a lack of substantial progress.

Availability of glucometers, a critical tool for diagnosis of DKA, was low across higher and lower-level facilities. In Nepal, for example, glucometers were available at only 17% of secondary and tertiary facilities. Only Malawi and Tanzania reported availabilities in the range of 80–100% at their higher-level facilities. Item availability was lower in lower-level facilities, where four of nine countries had less than 25% of lower-level facilities with the full glucometer set. This is alarming because the lack of availability of this simple diagnostic tool likely means DKA is inadequately diagnosed and managed in many LLMICs. As a result, delayed or misdiagnosed DKA can place patients at danger of complications and death.[22,23]

In terms of treatment, we found low availability of insulin, reinforcing global concern for lack of this item in low-resource settings.[2] Facilities without insulin will be unable to treat patients who present with DKA.[24] Treatment will have to be delayed until the patient is transferred to a facility with capacity to treat, which can place the patient at further danger of complications and mortality.[25] In addition, evidence from LLMICs has shown that children without consistent access and use of insulin for T1D management are more likely to develop DKA compared to those consistently using insulin.[26–28] Despite adequate initial management of a patient presenting with DKA, insecure access to insulin risks repeat DKA episodes. Given that insulin had the greatest influence on availability of the minimal set of supplies in at least one facility service level in Bangladesh, Haiti, Malawi, Nepal, and Tanzania, improved access is required to increase health system capacity to manage DKA and avoid serious morbidity or mortality.

This study had several limitations. Most of these limitations would lead to overestimates of facility capacity to manage DKA. First, SPA surveys do not include several of the items in our minimal and ideal sets to diagnose and treat DKA, and proxy items were used in certain cases. These missing items include insulin disaggregated by type, potassium, insulin syringes, glucagon, mannitol, IV pumps, urine ketone tests, blood chemistry analyzers, and diabetes guidelines specific to DKA management. Assuming availability of these items was less than 100%, we have almost certainly overestimated the true availability of item sets. Second, SPA surveys do not provide evidence about quality of services provided or specialty services, only the availability of medications, equipment, and guidelines. If many providers don't have adequate know-how or make errors in their management of DKA, this again would have led us to overestimate facility capacity to address this condition. In addition, the summary service readiness score weights all items equally, and does not account for indicators with greater necessity than others to manage DKA. To mitigate this, we have adapted and reported this score for minimal set of supplies, full minimal set, and ideal set.

Other study limitations may have led us to underestimate facility capacity to manage DKA. Information on item availability was taken from the outpatient and/or NCD service area for seven countries, whereas DKA patients would likely present to emergency services. To better understand how this may have impacted results, we conducted a sensitivity analysis on the countries with emergency service modules available and concluded our findings are robust. An additional limitation which may have potentially led to underestimation of current capacity to manage DKA is that the available SPA surveys were somewhat dated. However, given recent issues with COVID-19, it would not be surprising if health facility capacity has remained the same or decreased since the time these surveys were conducted. To address these limitations in the future, we highlight the need more frequent and standardized measurement of health system capacity for diagnosis and management of severe, chronic NCDs, that include emergency service data.

In conclusion, we found shockingly low capacity to manage DKA across health systems in nine LLMICs. We found that rural, public, secondary facilities with lower staff numbers were significantly less ready to diagnose and manage DKA. Health system capacity was highest in tertiary facilities in LLMICs, limiting access to care. In response to this issue, several initiatives have been established to improve capacity and access to T1D care at secondary facilities, including the WHO PEN-Plus model for integrated care of severe and complex NCDs.[29] With increased investment in the management of severe, chronic diseases in LLMICs, monitoring and evaluation will be needed to assess their impact. We outline the SPA's limitations in its ability to measure health system capacity to diagnose and manage DKA, and this study should guide future health facility assessments. As a crucial part of efforts to strengthen health systems in LLMICs and given our results showing lack of substantial improvement in capacity over time, we also recommend increased investments in emergency and high-dependency care, consistent with the recommendations of the Lancet NCDI Poverty Commission.[30] Without these investments, misdiagnoses and delayed treatment for DKA will continue to place patients at risk of preventable complications and mortality.

Contributors

Authors SM, MC, CT, GF, AA, and GB conceptualized the study. SM, MC, AB, CT, GF, NG, AA, and GB designed the methodology for analysis. SM did the statistical analysis with input and validation of results from MC. Authors WD, DF, TG, BK, NCL, AL, MTM, MDM, and GT reviewed the results and gave input as stakeholders in the countries assessed. SM wrote the original draft of the manuscript with input from MC, CT, GF, AA, and GB. All authors reviewed and edited the manuscript.

Data sharing statement

The data used in this analysis was obtained from the Demographic and Health Survey's Program's webpage and can be accessed at https://dhsprogram.com/data/new-user-registration.cfm for those who register for dataset access for legitimate research purposes.

Declaration of interests

All authors declare no competing interests.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.eclinm.2022.101759.

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