



# Knowledge and Confidence of Omani Pediatric Residents in Managing Diabetic Ketoacidosis: A Cross-Sectional Survey

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J Diabetes Endocrine Practice 2023;6:134–141.

## Abstract

**Introduction** Diabetic ketoacidosis (DKA) is a common complication of type 1 diabetes mellitus. Unfortunately, medical errors are not uncommon during the management of DKA leading to significant morbidity and mortality. There are many studies conducted to assess the knowledge of junior doctors in the management of DKA in many countries including Bahrain and Iraq.

**Objectives** This study aims to assess the knowledge and confidence of Omani pediatric residents in the management of DKA and compare the findings with the results of previous studies from the region.

**Materials and Methods** A cross-sectional study was conducted among all enrolled pediatric residents in the Oman Medical Specialties Board in 2021, using an online survey that consists of three parts with a total of 30 questions to gain information about demographics, knowledge, and overall confidence in the management of DKA in children. The questionnaire was adopted from the Bahraini and Iraqi studies.

**Results** In total, 69 pediatric residents (15M:54F) out of 84 had responded to the survey, giving a response rate of 82%. More than half of the responders were junior residents R1 and R2 (59.3%). The overall performance score of knowledge among the residents mainly ranged between 50 and 75%. However, R2 resident performance was better as their score ranged between 80 and 85%. Only 5.7% of our residents had a performance score above 90%. The overall confidence of residents in managing patients with DKA was directly proportional to their year of residency, ranging from not confident to very confident, demonstrating that most residents from R1 to R3 rated themselves as “fair” compared with 58.3% of 4th-year residents who rated themselves as confident. In comparison to similar studies in Bahrain and Iraq, our junior residents showed better knowledge in some aspects, for example, identifying the correct biochemical criteria to diagnose DKA, 88.7 vs. 65% from Bahrain and 20.7% from Iraq.

## Keywords

- ▶ type one diabetes mellitus
- ▶ diabetic ketoacidosis
- ▶ pediatric residents
- ▶ knowledge
- ▶ residents
- ▶ training
- ▶ education

article published online  
September 18, 2023

DOI <https://doi.org/10.1055/s-0043-1772453>.  
ISSN 2772-7653.

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**Conclusion** The overall knowledge and confidence of the Omani pediatric residents were satisfying. However, there are still some gaps in knowledge to be bridged about the management of pediatric DKA. Continuous educational activities are desired. Therefore, more sessions about DKA management are to be scheduled, perhaps applying some simulation training to boost their knowledge and confidence.

## Introduction

Diabetes mellitus is a group of diseases characterized by abnormally high blood glucose levels. Type one diabetes mellitus (T1DM) accounts for around 10% of all cases of diabetes across all age groups, but it accounts for more than 90% of diabetes mellitus in children.<sup>1</sup> It is an autoimmune disease resulting from cellular dysfunction of pancreatic  $\beta$ -cells affecting its ability to produce enough insulin that is required to maintain a stable blood glucose level.<sup>2</sup> Globally, the incidence of T1DM is 15 per 100,000 people and the prevalence is 9.5%.<sup>3</sup> Most recently, the 10th edition (2021) of the International Diabetes Federation (IDF) atlas reported that diabetes is rapidly growing worldwide, with the highest incidence rate of T1DM in children between 0 and 14 years old in Finland and Sweden with 52.2 and 44.1 per 100,000 population per year followed by Kuwait and Qatar 41.7 and 38.1 per 100,000 population per year, respectively,<sup>4</sup> whereas the incidence rate of T1DM in Oman among the pediatric age is 2.5 per 100,000.<sup>5</sup> The frequency of DKA as a first presentation of T1DM varies from 15 to 67% in various studies.<sup>6</sup> It was reported to be 33.6% in Kuwait,<sup>7</sup> 44.9% in Saudi Arabia,<sup>8</sup> and 31% in Oman.<sup>9</sup>

Diabetic ketoacidosis (DKA) is a common and life-threatening complication of T1DM, resulting from an insulin deficiency and an increase in other counter-regulatory hormones. This would enhance the hepatic production of glucose and increase fat catabolism leading to high levels of ketones and metabolic acidosis. The overall mortality rate of DKA in Arab countries was not thoroughly studied and published; however, according to the available literature, it ranges between 0.21% and 12.9%.<sup>10</sup> Cerebral edema (CE) is one of the major and serious complications that can be associated with inappropriate management of DKA. Different factors may play a role in the development of CE such as high serum urea, hyponatremia, and hyponatremia.<sup>11</sup>

Although DKA is a commonly encountered medical case, unfortunately, medical errors in its management still occur leading to significant mortality and morbidity.<sup>12</sup> Variable protocols had been used in different institutions and specialties including emergency departments, general wards, and intensive units. These nonunified protocols could sometime be leading to controversies to obtain optimal management and sometimes they could lead to an increase in the risk of some complications such as CE.<sup>13</sup> A study was conducted in 1997 to compare different DKA management strategies among physicians from different specialties including emergency physicians, endocrinologists, pediatric residents, and general pediatricians. Significant differences

in the approach and management of DKA among different specialties were shown.<sup>14</sup> That pointed toward the importance of having a unified protocol for the management of DKA that helps in improving the quality of care and minimizing errors and thereby reducing the mortality and morbidity associated with DKA and its management. That has also driven scientific societies and institutions to standardize their protocols in the management of DKA when possible. Once that was achieved, the next step was to make sure that treating doctors are aware of these updated guidelines. Especially when it is not uncommon that junior members of variable admitting teams initiate the management of those patients presenting with DKA without involving pediatric diabetic specialist teams (DST). For that, our study was conducted to assess the knowledge and the confidence of Omani pediatric residents in the recognition and appropriate management of DKA to identify any gaps in knowledge that we could work on to minimize medical errors and improve overall patients care in Oman. The findings of our study were made comparable to similar and recently published work from Iraq and Bahrain. The pediatric residency program in Oman is a 4-year program that starts after the successful completion of an internship year. Residents have a weekly educational half-day and throughout their program, they have access to several workshops and educational activities such as grand rounds, registrar quizzes, and journal clubs. Additionally, pediatric residents in Oman have an informal pediatric study group on social media that is managed voluntarily by a group of pediatricians from different specialties that enables them to discuss a variety of cases daily.

## Materials and Methods

Our study is a cross-sectional study that included all pediatric residents enrolled with the Oman Medical Specialties Board (OMSB), from year 1 to year 4 of residency in 2021. Data were collected by using an online survey distributed among pediatric residents in OMSB. The questionnaire was originally developed, validated, and cascaded by a group of pediatric endocrinologists from Iraq and Bahrain. We adopted the same questionnaire, and the knowledge questions were mainly based on the 2020 DKA management guideline from the British Society of Pediatric Endocrinology and Diabetes (BSPED).

It contains 30 questions, the first part of which assessed the resident's general knowledge of DKA and its diagnostic criteria. The second part of the questionnaire evaluated residents' knowledge about four main domains in DKA

management including (1) fluid management, (2) insulin therapy, (3) treatment monitoring, and (4) involvement of a senior physician. The third part was to evaluate their overall confidence using the Likert scale and their willingness to have extra sessions or workshops. The questions were directed toward clear points in the assessment and management of DKA, avoiding any controversial issues.

## Data Analysis

All data were collected using Survey Monkey, a commercial online Web site. Data were analyzed using the SPSS program. Statistical significance was considered when  $p$ -value was  $<0.05$ .

## Results

In total, 69 pediatric residents (15M:54F) out of 84 had responded to the survey, giving a response rate of 82%, more than the received responses from the Bahraini and Iraqi residents (42 and 41 responses, respectively). More than half of our responders were junior residents R1 and R2 (59.3%). Among involved residents, 10.1% did not complete any emergency block during their training so far, 34.8% completed two blocks, and 42% completed more than four blocks. Each block of training is 4 weeks in duration. The number of DKA cases managed by the majority of residents (65%) is around five cases during their training at the time of responding to our questionnaire. None of the responded residents is diagnosed with diabetes mellitus. The rationale for mentioning this is we would have excluded their responses from our analysis to avoid any bias since the person who lives with diabetes is has more exposure to the condition which probably gives higher knowledge about diabetes and DKA compared with the others. ► **Table 1** shows the characteristics of the responded residents.

(1) Assessing knowledge of diagnosing DKA and classifying its severity.

Two clinical scenarios were provided, to assess the ability of residents to recognize the clinical features of DKA. The percentage of correct answers among candidates was 92.8%, in which 96.9% of senior residents (R3–R4) and 89.9% of junior residents (R1–R2) were able to identify the correct answer. In total, 92.7% of senior residents (R3–R4) and 88.7% of junior residents (R1–R2) were able to identify the correct biochemical criteria to diagnose DKA. Surprisingly, the DKA severity classification was answered correctly only by 65.6% of senior residents compared with 79.6% of junior residents. ► **Table 2** shows a comparison of the received responses according to the training level.

(2) Fluid management.

Five questions were provided to assess the knowledge of the trainees in fluid management of patients presenting with DKA. Unfortunately, only 27.5% of residents chose the correct type of initial intravenous fluid recommended to be used in DKA. As shown in ► **Table 2**, the highest percentage of correct

**Table 1** Participant characteristics

Characteristics	Value	Percent%
Gender		
Male	15	21.7
Female	54	78.3
Residency level		
1	24	34.8
2	17	24.6
3	16	23.2
4	12	17.4
Number of completed emergency blocks		
0	7	10.1
1	3	4.3
2	24	34.8
3	6	8.7
≥4	29	42
Diabetes Miletus among residents		
Yes	0	0
No	69	100
Initial self-assessment and rating		
Very good	7	10.1
Good	39	56.5
Fair	21	30.4
Not sure, I don't know	2	2.9
Number of DKA cases managed by residents		
None	7	10.1
< 5	45	65.2
5–10	16	23.2
> 10	1	1.4

answers was among R3 (31.3%) followed by R1 (29.1%) and R4 (25%) and R2 (23.5%). The second question was about the amount of initial bolus in severe DKA in a patient presenting without a shock and it was answered correctly by 79.7% of residents. The highest percentage (91.7%) was in R4 and the lowest was in R1 (66.7%). The third question was about the amount and rate of fluid correction in patients with DKA found to be in a shock, 57.9% chose to give fast and full fluid bolus while 42.03% of residents preferred to give half fluid bolus over 30 to 60 minutes. The fourth question was about the rate of fluid maintenance, 71% of trainees were aware of the correct equation used to calculate the intravenous fluids over 48 hours. The majority of this cohort (89.9%) decided to add glucose to the running fluid when blood glucose drops below 14 mmol/L during acute management of DKA.

(3) Insulin therapy

Regarding the timing of starting insulin therapy, 88.4% of the residents would initiate insulin therapy after 60 minutes

**Table 2** Comparison of the received responses according to the training level

Questions	Percentage of correct answers among resident	Residency level				Junior resident (R1 + R2) N = 41	Senior residents (R3-R4) N = 28	p-Value Between (R1-2) vs. R3-4s
		R1 N:24	R2 N:17	R3 N:16	R4 N:12			
DKA diagnosis and severity classification								
Clinical features of DKA	92.8%	91.6%	88.2%	93.8%	100%	89.9%	96.9%	0.332
Biochemical criteria for DKA diagnosis	89.9%	83.3%	94.1%	93.8%	91.7%	88.7%	92.7%	0.496
Determining the severity of DKA	72.5%	83.3%	70.6%	56.3%	75%	76.9%	65.6%	0.205
Fluid management								
Type of initial fluid in DKA management	27.5%	29.1%	23.5%	31.3%	25%	26.3%	28.3%	0.872
Amount of initial bolus in severe DKA without shock	79.7%	66.7%	88.2%	81.3%	91.7%	77.4%	86.5%	0.423
Amount of initial fluid bolus in DKA with shock	58%	62.5%	58.9%	56.3%	50%	60.7%	53.1%	0.541
The rate of fluid infusion	71%	70.8%	64.7%	75%	75%	67.7%	75%	0.548
Indication of adding dextrose to IV fluid	89.9%	87.5%	82.4%	87.5%	75%	84.9%	81.2%	0.718
Monitoring								
Parameters need to be monitor during DKA management	89.9%	83.3%	88.2%	100%	91.7%	85.7%	95.8%	0.136
Frequency of Glucose monitoring	75.4%	79.2%	76.5%	68.8%	75%	77.8%	71.9%	0.528
frequency of cardiac monitoring	92.8%	91.7%	82.4%	93.8%	100%	87%	96.9%	0.211
Complication								
Awareness of sign and symptoms of cerebral edema	94.2%	95.8%	94.1%	93.8%	91.7%	94.9%	92.7%	0.689
Dealing with hypoglycemia	56.5%	45.8%	64.7%	56.3%	66.7%	55.2%	61.5%	0.703
Awareness of Electrolytes disturbance in DKA	100%	100%	100%	100%	100%	100%	100%	-
Insulin therapy								
Timing for starting insulin infusion	88.4%	91.7%	82.4%	100%	75%	87%	87.5%	0.849
Switching from IV to SC insulin	84.1%	70.8%	94.1%	81.3%	100%	82.4%	90.6%	0.459
Others								
Avoiding use of sodium bicarbonate in DKA management	94.2%	95.8%	88.2%	100%	91.7%	92%	95.8%	0.515
Notifying senior immediately	75.4%	91.7%	76.5%	75%	41.6%	84.1%	58.3%	0.018

Abbreviations: DKA, diabetic ketoacidosis; IV, intravenous; SC, subcutaneous.

from starting the intravenous fluids. However, 10.1% of the trainees choose to start insulin as soon as they made the DKA diagnosis. In total, 90.6% of senior residents (R3-R4) and 82.4% of junior residents (R1-R2) recognized the correct criteria to switch from intravenous to subcutaneous insulin.

#### (4) Monitoring

Most of the trainees, 89.9% were aware of the important parameters that need frequent monitoring during DKA management. In total, 92.8% of residents would like to do cardiac monitoring every 2 to 4 hours; however, only 75.4% of them

want to check blood glucose level hourly, whereas 18.8% of residents will check it every 2 hours (– Table 2).

#### (5) Complications

Three questions were provided to assess the knowledge of the residents approximately four main complications of DKA including CE, hypoglycemia, electrolyte disturbances, and arrhythmia. In total, 94.4% of this cohort would inform their senior immediately if a patient with DKA developed a headache reflecting their awareness about symptoms of CE. On the contrary, there were variations in the trainee's management plan of hypoglycemia during DKA management, 55.1% of them will increase the dextrose concentration in intravenous fluid, 11.9% will give a bolus of 10% dextrose, 7.25% prefer to stop insulin temporarily, while 21.7% chose to stop insulin temporarily, give a bolus, and increase the dextrosity of the fluids. Almost all residents were aware that cardiac arrhythmia could result from a disturbance in potassium level during DKA, and most of them (97.8%) thought hypokalemia is the main cause of arrhythmia in DKA.

#### (6) Notifying the senior physician and involvement of the on-call endocrinologist

In total, 91.7% of 1st-year residents and 76.5% of the 2nd-year residents would involve their senior immediately as soon as they diagnosed pediatric patient with DKA, compared with 41.6% of 4th-year residents. However, 25% of residents in their fourth year of training choose to inform seniors after giving the first fluid bolus and 25% will involve seniors only once it is becoming difficult to manage.

– Table 3 showed a comparison in responses regarding timing of endocrine consultations among residents at different training levels. In total, 70.7% of junior residents and 71.4% of senior residents prefer to consult an endocrinologist while the patient is still in the emergency room, and 7.3% of junior residents and 14.3% of senior residents would consult endocrine on-call within 2 hours of admitting the child. However, 7.3% of junior residents and 33.6% of senior residents would involve endocrinologists only if the child required intubation and PICU admission. The rest of the residents were not sure when to consult the on-call pediatric endocrinologist.

#### (7) Need for extra teaching sessions.

The majority of the residents (88.4%) feel they need extra teaching sessions to improve their knowledge and confidence in DKA management.

## Discussion

DKA remains the most common cause of death in children and adolescents with T1DM. CE, the serious complication of DKA, is the most frequent cause of death in DKA. CE usually develops after 4 to 12 hours from initiation of fluid therapy. Since DKA is one of not uncommon emergency conditions. Therefore, we aimed to assess the knowledge of our frontline junior doctors by conducting this cross-sectional study. Our study enrolled 69 out of 84 residents with a very good response rate. In total, 45 and 70 residents from Bahrain and Iraq, respectively, previously responded to the same questionnaire, for which we are making a comparison.<sup>15,16</sup> The knowledge of our residents regarding the clinical features, biochemical criteria, and DKA severity grading was sufficient, with no significant difference between different training levels. In our study, 88.7% of junior residents (R1–R2) and 92.7% of senior residents (R3–R4) were able to correctly identify the biochemical criteria to diagnose DKA based on BSPED guidelines (hyperglycemia with blood glucose >11 mmol/L, venous pH < 7.3 or serum bicarbonate < 15 mmol/L with ketonemia > 3 mmol/L or ketonuria ++), this percentage was much higher compared with the study done among Bahraini and Iraqi residents. Ali et al found that 65 and 86.4% of R1–R3 and R4, respectively, were able to correctly diagnose DKA, whereas a lower rate was observed among the Iraqi residents where only 20.7% of R1–R3 and 45.5% of R4 could correctly identify the diagnostic criteria of DKA.

Generally, the awareness regarding DKA management was adequate; however, the area with the lowest score was related to fluid management, which is one of the most important aspects of DKA management. Our results showed residents were aware of the amount of fluid used for resuscitation, the equation of calculating the rate of maintenance fluid and indications of adding dextrose to the infused intravenous fluid with a percentages of correct answers ranging between 60–80%. Surprisingly the main gap in

**Table 3** Comparison in response regarding timing of endocrine consultations among residents at different training levels

Timing of notifying endocrinologist	R1	R2	R3	R4	Junior R1–R2	Senior R3–R4
While the patient still in emergency room	16(66.7%)	13(76.5%)	10 (62.5%)	10 (83.3%)	29 (70.7%)	20 (71.4%)
Within 2 h of admitting the child	2 (8.3%)	1 (5.88%)	3 (18.75%)	1 (8.33%)	3 (7.3%)	4 (14.3%)
Only if the child had required PICU admission	3(12.5%)	0	0	1 (8.33%)	3 (7.3%)	1 (3.6%)
Not sure	3 (12.5)	3 (17.6%)	3 (18.75%)	0	6(14.6%)	3 (10.7%)

Abbreviations: PICU, pediatric intensive care unit.



knowledge was identifying the correct type of initial intravenous maintenance fluid, only 27% of residents got the correct answer (0.9% saline and 20 mmol potassium chloride in 500 mL bag) with no significant difference among different trainees' levels. Most of the residents (68.1%) choose to give normal saline without adding potassium to it. One possible explanation for their answer is that they prefer to wait for the laboratory results to know the exact level of serum potassium before adding potassium chloride to the infused fluids, although all guidelines recommend adding potassium to the infused fluid and then adjusting the amount of potassium concentration according to the serum potassium level unless the patient is hyperkalemic.<sup>17,18</sup> These results were in line with the findings from the other studies that we are comparing with.

Another major deficit in knowledge was noticed in the ability of residents to deal with hypoglycemia during DKA management, while the acidosis was still not corrected. The percentage of correct answers among junior residents was 55.2% and senior residents 61.5% with no statistical significance between different training levels. Although our local protocols clearly recommend avoiding stopping insulin infusion if biochemical markers of DKA (venous pH, anion gap, ketones) have not normalized, 7.25% of residents prefer to stop insulin temporarily. Similar results with even much lower awareness were found in the Bahrani study.<sup>15</sup> This might reflect the lack of awareness of the importance of insulin therapy not only for normalizing blood glucose but rather for restoring normal cellular metabolism, to suppressing lipolysis and ketogenesis.

Our study revealed that residents in different training levels have adequate knowledge about the correct timing of initiation of insulin infusion and the criteria for switching from intravenous to subcutaneous insulin. These results were relatively like the other results from the other studies that we are comparing with. More than 94% of our residents were aware of the recent guidelines that discourage the use of sodium bicarbonate during DKA management due to the increased risk of CE, compared with 92 and 88% of Iraqi and Bahraini residents, respectively.

The overall confidence of residents in managing a patient with DKA ranged from fair to confident on the Likert scale, and it was directly proportional to residency level. In total, 33.33% of R4 felt they have a "fair" confidence level in managing DKA, while 58.33% of them were "confident" and 8.33% were "very confident." However, 11.67% of 2nd-year residents were not confident at all in managing DKA. Similarly, the result of the initial self-assessment and rating ranged from "poor/not sure" to "very good," showing that most of the residents rated themselves between "fair" and "good." In total, 41.67% of 4th-year residency level rated themselves as "very good" and 14.67% rated themselves as "good." In comparison to the 1st-year residents, more than half rated themselves as "good" (58.33%) and 37.5% as "fair." These results reflect their response on timing to involve their seniors, 91.7% of the 1st-year residents and 75% of 2nd-year residents would involve their senior immediately as soon as

they diagnose a patient with DKA, compared with 41.6% of the 4th-year residents. A quarter of the 4th-year residents would choose to inform their seniors after giving the first fluid bolus and the other quarter of them would involve seniors only once it is difficult to manage. Similar results were found in the Bahrani study, most of 1st-year residents prefer to call a senior doctor immediately, while 45.4% of 4th-year residents would only involve seniors when they face difficulty in the management. Although the British Society of Pediatric Endocrine and Diabetes recommended consulting a more senior doctor on-call as soon as a case of DKA is suspected as the patient can deteriorate very quickly.<sup>16</sup>

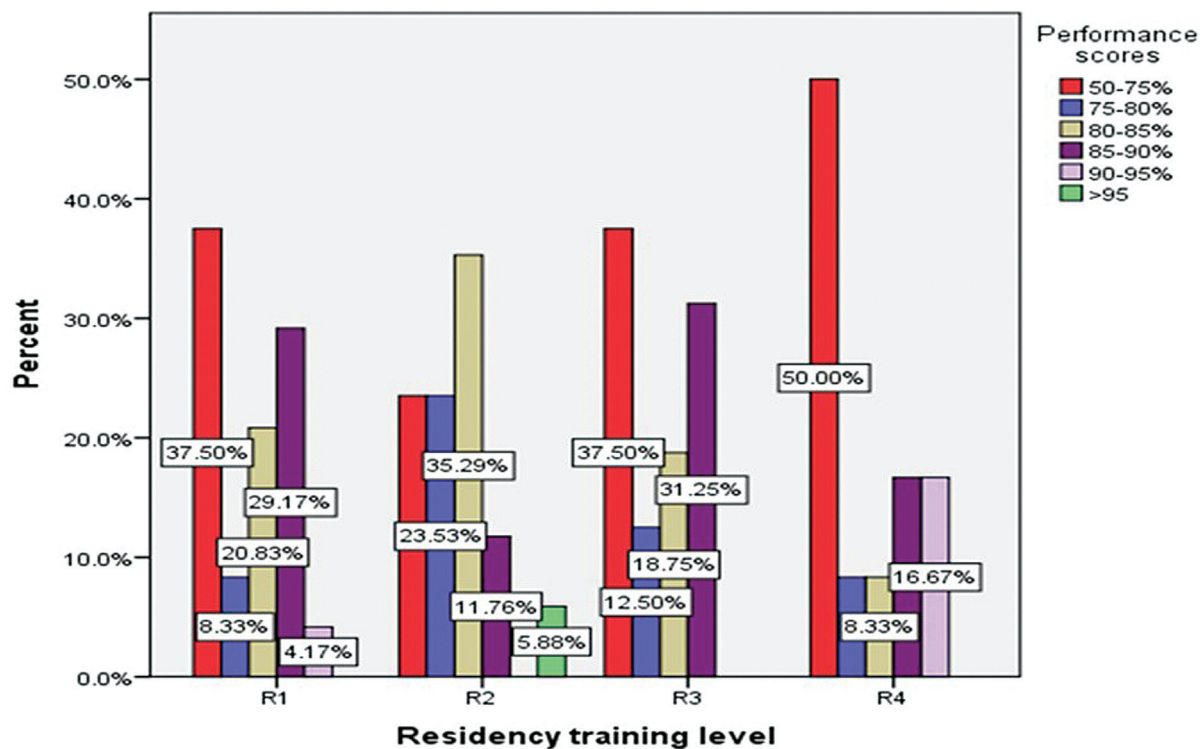
► **Table 3** showed the response of participants regarding when to consult endocrinologists, most of the residents from different residency levels prefer to involve endocrinologists while the patient is still in the emergency room. However, 14.6% of junior residents and 10.7% of senior residents were not sure when to inform the endocrinologist. This question was more of exploratory as there was no clear consensus and recommendation for the timing of when to consult the pediatric endocrinologist/diabetologist. Although Joint British Diabetes Societies highly recommended to involve DST during the acute phase of DKA and patient should not be discharged home before being reviewed by the specialized team as it would improve management outcomes, shorten the duration of stay in the hospital, and optimize patient safety.<sup>19</sup>

The overall assessment and scoring of our residents revealed that 36.2% of residents answer around 50 to 75% of questions correctly, 23% of them got 80 to 90% score of correct answers, and only 1.4% of residents got more than 95% correct answers (► **Fig. 1**). Generally, the knowledge and awareness of our trainees was better compared with the recently published studies from Bahrain and Iraq. This might reflect the benefit of the formal and nonformal academic teachings of Omani residents that includes frequent assessments and evaluations of residents with encouragement to read more and be updated about the new guidelines. Nevertheless, more comprehensive teaching and workshops with variable clinical scenarios are needed to make sure that residents can deal with DKA and its possible complications appropriately without making any mistakes.

One of the limitations of our study is that the questionnaire was distributed to the residents without monitoring the time used for answering the questions that limited their access to online or hard copy resources that might use to help them in answering the questions, which might result in false high scoring. Saying that, in practice, doctors are not prohibited to use any available online source of guideline to manage DKA as far as this guideline is endorsed by a recognized authority, group, or society.

## Conclusion

The overall knowledge and confidence of the Omani pediatric residents were satisfying. However, there are still some gaps in knowledge to be bridged about the management of pediatric DKA. Continuous educational activities are desired.



**Fig. 1** Overall performance score among different training levels.

Therefore, more sessions about DKA management are to be scheduled and perhaps applying some simulation training to boost their knowledge and confidence.

#### Compliance with Ethical Principles

The study was approved by the ethical committee of OMSB. Informed consent was provided by participants.

#### Authors' Contribution

H.A. conceptualized the idea of this research. M.A. collected and analyzed the data. M.A. drafted the manuscript and H.A. reviewed it. Both authors agreed on the final version.

#### Funding and Sponsorship

None.

#### Conflict of Interest

None declared.

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