Sustaining improvement in Diabetes-related ketoacidosis management through Quality Improvement Project

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Sandwell and West Birmingham NHS Trust

Walsall Hospitals NHS Trust

University Hospitals Birmingham NHS Foundation Trust

Layout

Brief Intro about DKA and QIP

Hypothesis and how QI started

Initial results with interventions

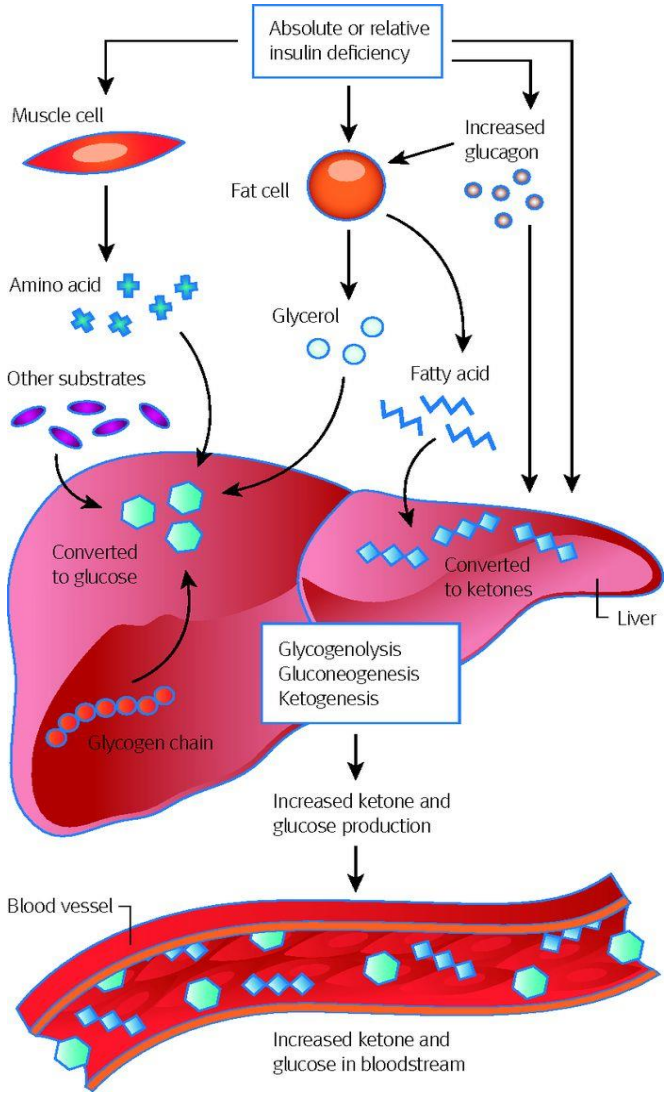
Follow-up findings without any interventions

Can QI go beyond improvement

Sharing our learning with each other

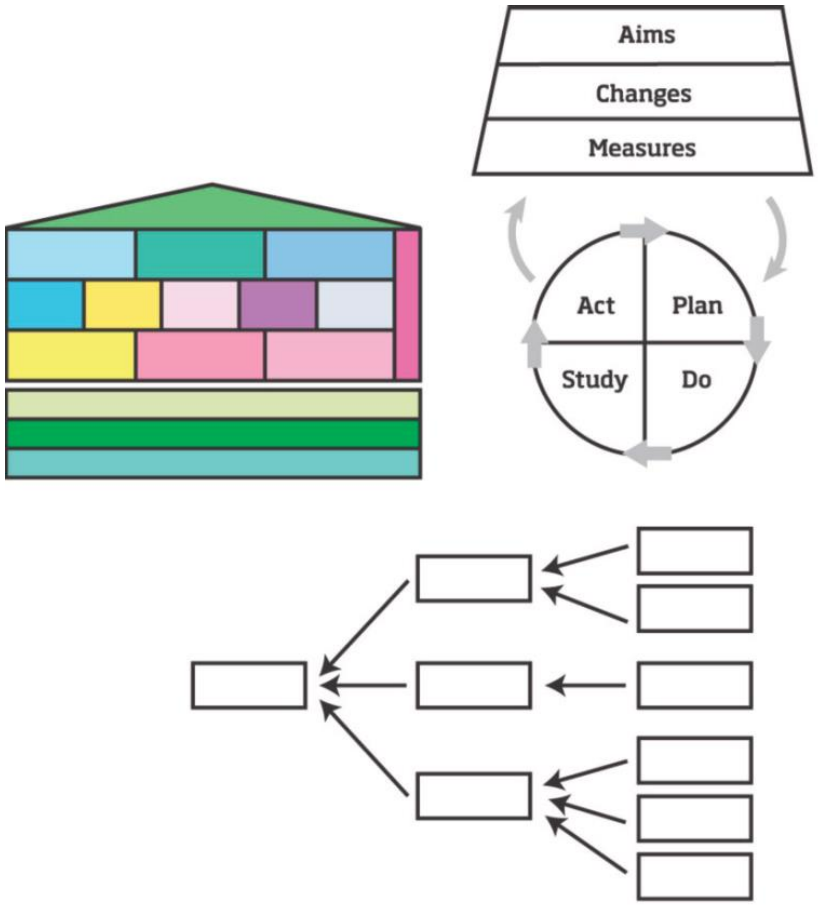
Background

- Diabetic ketoacidosis (DKA)- extreme metabolic state due to insulin deficiency.
- Joint British Diabetes Society (JBDS) guidelines in 2010; further revised in 2013 and 2021
- Many trainee doctors and frontline staff are not fully confident in managing DKA.

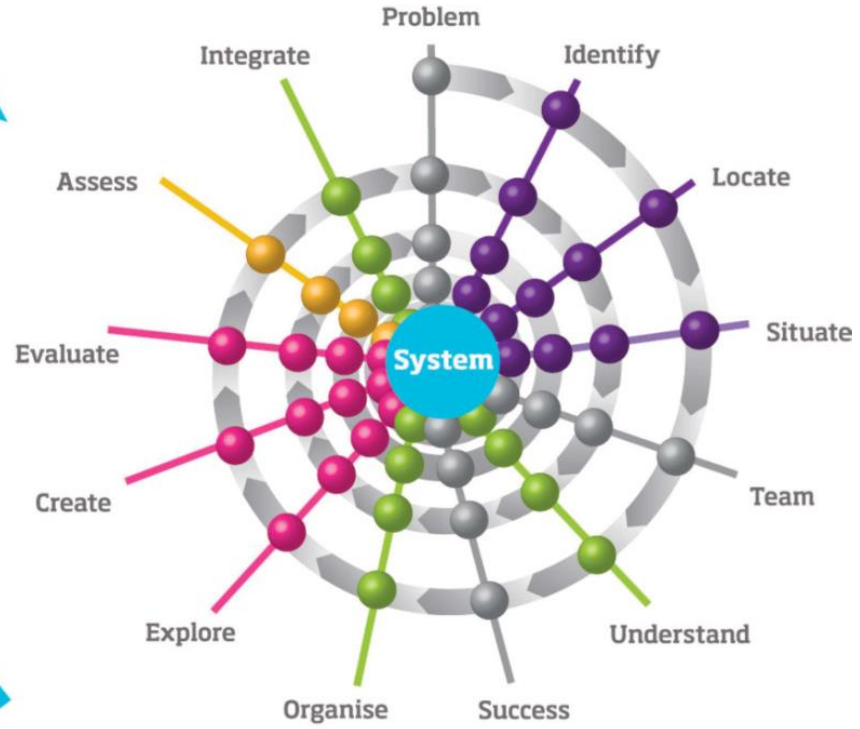


Gibbs et al. Diabetologia. 2016
Savage et al. Diabetic Medicine. 2011

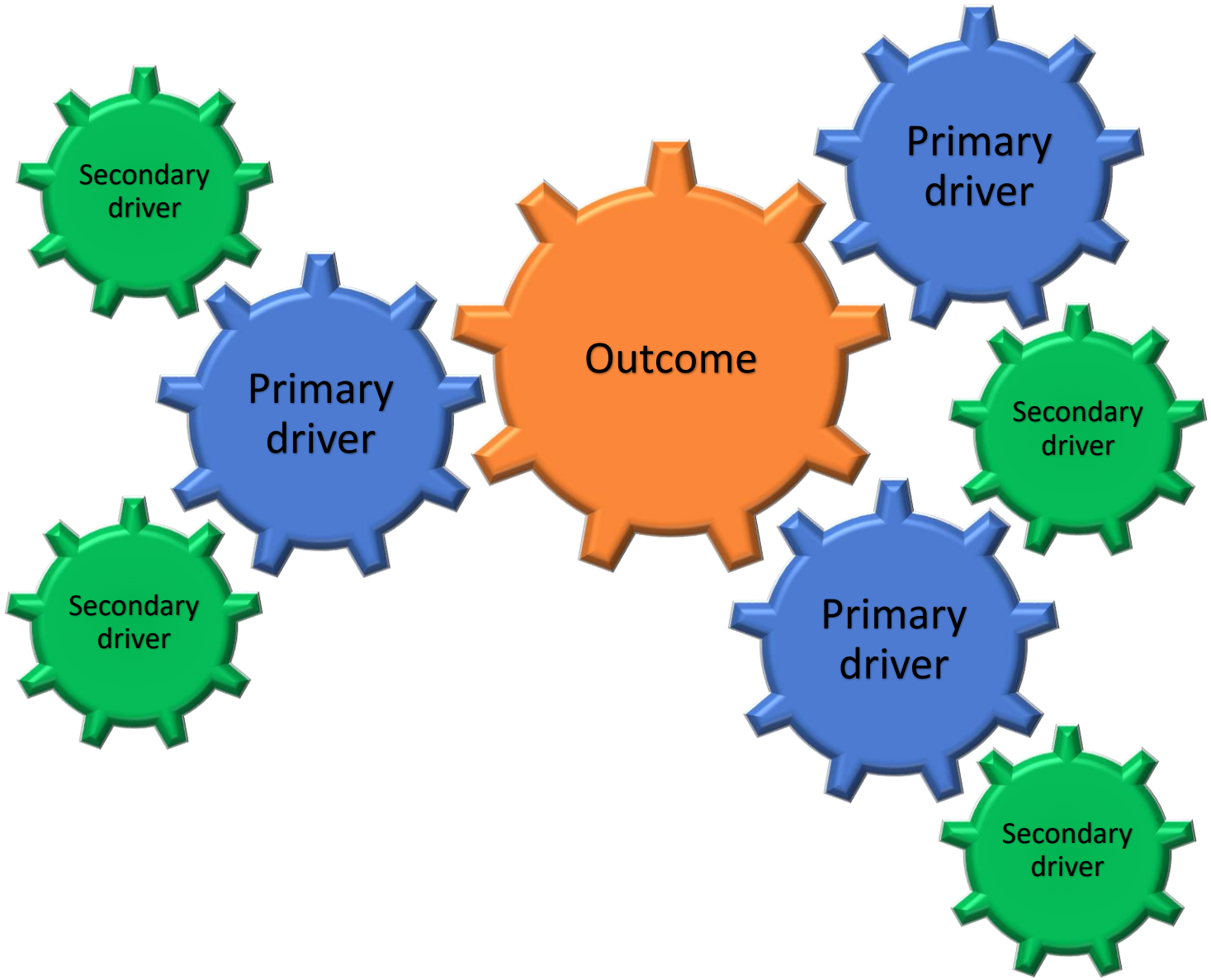
Quality Improvement



Improvement tools

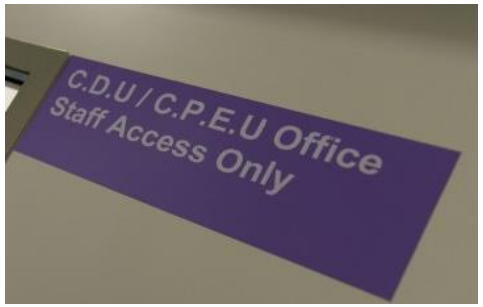


Systems approach


Secondary driver
Primary driver
Outcome
Primary driver
Secondary driver
Secondary driver
Primary driver
Secondary driver

Hypothesis

Implementing a QI for limited clinical criteria and frequent feedback improves DKA management



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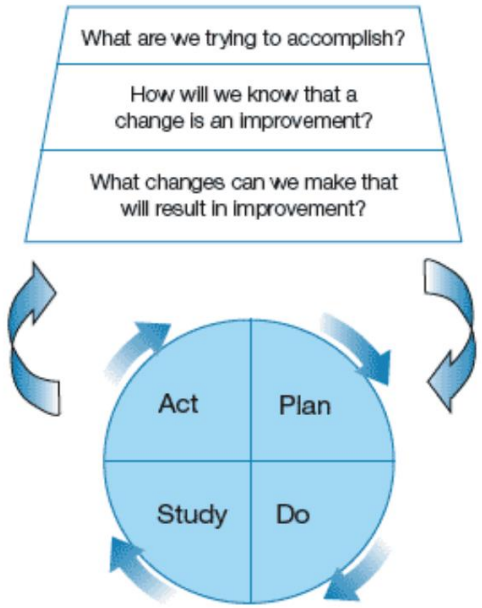
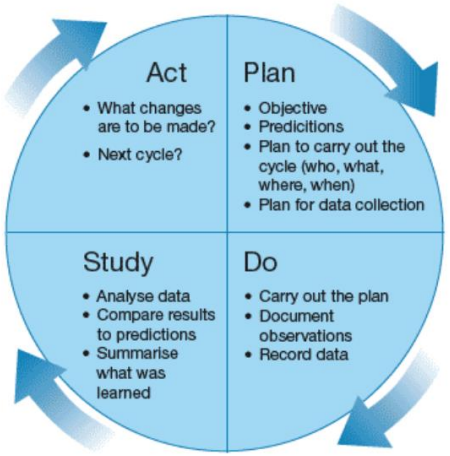
Methods

- All patients diagnosed with DKA from April 2014 to September 2016 were included.
- Patients managed in intensive care units were excluded from the study to avoid one-to-one care bias.
- We adopted the plan-do-study-act (PDSA) method for the QIP

Model for Improvement
Langley et al, 1996



Plan Do Study Act cycle



Primary drivers, Secondary drivers and outcomes

Duration of DKA

Clinical
- Emergency medicine
- Acute medicine
- Department of diabetes

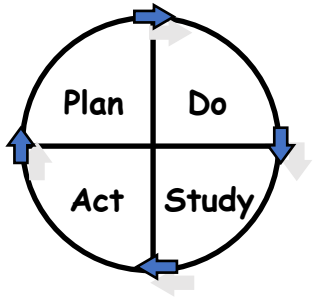
- **Fluids**
- **Fixed rate insulin infusion (FRII)**
- **Glucose measurements**
- **Ketone measurements**
- **Specialist referral**

Non-clinical
- Bed management
- Clinical governance
- Information-technology

Acute Medicine
Confirming diagnosis
Optimising treatment
Hourly measurements

Emergency department
Diagnosis
Initiation of treatment
Transfer to Acute Medicine

Department of Diabetes
Early referral
Discharge planning
Follow-up



Bed management
Transfer of patients from ED to CDU and then to appropriate ward

Information technology
Optimising all referrals and providing appropriate patient list

Clinical Governance
Permit to undertake the QIP and approve amendments in the guidelines

Oct 2014- QIP initiated

Nov 2014- Automatic Referral and fluid

Dec 2014- FRII and hourly measurements

Jan 2015- Blood gases on electronic patient records

Feb 2015- Introducing DKA mnemonic

Mar 2015- Revamping DKA protocol

Management of DKA

A to K & D

- **A** Airway
- **B** Breathing
- **C** Circulation
- **D** Diabetes
- **E** Electrolytes and pH
- **F** Fluid replacement
- **G** Hourly Glucose
- **H** HbA1C
- **I** Fixed rate Insulin
- **J** Clinical Judgement
- **K** Hourly Ketones

and

- **D** Diabetes team referral

DIAGNOSTIC CRITERIA

All three of the following must be present

- Capillary blood glucose above 11 mmol/L
- Capillary ketones above 3 mmol/L or urine ketones ++ or more
- Venous pH less than 7.3 and/or bicarbonate less than 15 mmol/L

IMMEDIATE MANAGEMENT: 0 – 60MINS

Action 1 – Restore circulating volume

Commence 0.9% sodium chloride solution intravenous infusion via infusion pump. A systolic blood pressure of 90mmHg may be used as a measure of hydration but consider age, gender, body mass index, possibility of sepsis and cardiac, liver and renal failure into account.

If systolic blood pressure on admission is below 90mmHg
- Give 500ml of 0.9% sodium chloride over 10-15mins. If systolic blood pressure remains below 90mmHg, this may be repeated. In practice most patients require 500-1000ml given rapidly
- Once systolic blood pressure above 90mmHg, give 1L of 0.9% sodium chloride over next 60mins. Addition of potassium likely in this second bag

If systolic blood pressure on admission is above 90mmHg
- Give 1L of 0.9% sodium chloride over 60mins.

Action 2 – Start fixed rate IV insulin infusion (FRII)
- Start continuous FRII via an infusion pump (50 units human soluble insulin (Actrapid or Humulin S) made up to 50ml with 0.9% sodium chloride).
- Infuse at a fixed rate of 0.1unit/kg/hr (e.g. 7ml/hr if weight is 70kg). Estimate weight if you have to.
- Only give a stat dose of intramuscular insulin (0.1 unit/kg) if there is a delay in setting up a FRII.
- Continue any long acting insulin (Lantus or Levemir or others) subcutaneously at the usual dose and usual time
- Insulin may be infused in the same line as the intravenous replacement fluid provided that a Y connector with a one way, anti-syphon valve is used and a large-bore cannula has been placed

Action 3 – Assess patient and treat precipitating causes
- Airway, breathing and circulation
- Full systemic examination
- Assess for foci of infection if any

Action 4 – Recommended Investigations
- Blood gas analysis
- Full blood count
- Liver function test
- Renal function test
- Blood culture
- Urine analysis +/- culture
- Chest X-ray
- Pregnancy test

Other investigations as felt appropriate.

Action 5 – Establish monitoring regimen
- Hourly capillary blood glucose
- Hourly capillary ketone measurement if available
- Venous bicarbonate and potassium at 60 minutes, 2 hours and 2 hourly thereafter
- 4 hourly plasma electrolytes
- Continuous cardiac monitoring if required
- Continuous pulse oximetry if required

Delivering the best in care

IF INADEQUATE RESPONSE TO TREATMENT

- Always check the insulin infusion pump is working and connected, and that the correct insulin residual volume is present (to check for pump malfunction)
- If inadequate response to treatment, increase insulin infusion rate by 1unit/hr increments hourly until targets achieved
- Seek senior review if no clinical improvement/ inadequate response to treatment

CONSIDER HDU REFERRAL

- Young (18-25yr old) or elderly
- Pregnancy
- Heart or kidney failure, other co-morbidities
- Severe DKA as judged by
  - Blood ketones >6mmol/L
  - Venous bicarbonate <5mmol/L
  - Venous pH <7.1
  - Hypokalaemia on admission
  - GCS<12
  - Oxygen sats <92%
  - Pulse >100 or <60 bpm
  - Anion gap >16 [calculated as (Na+K)-(Cl+HCO3)]

THINKGLUCOSE™
Inpatient care for people with diabetes

60 MINUTES TO 6 HOURS

Action 1: Reassess patient, monitor vital signs, establish monitoring regimen
- Hourly blood ketones and glucose
- Venous blood gas for pH, bicarbonate and potassium at 1, 2 and 4hours (more frequently if outside the normal range).

Action 2: Continue fluid and potassium replacement
- 1L 0.9% NaCl with KCl: next 2hrs
- 1L 0.9% NaCl with KCl: next 2hrs
- 1L 0.9% NaCl with KCl: next 4hrs
- If glucose falls below 14 mmol/L commence 10% glucose given at 125mls/hour alongside the 0.9% sodium chloride solution.
- Supplement fluids with potassium according to blood K+ (mmol/L):
  - >5.5: No potassium replacement
  - 3.5-5.5: 20mmol per litre of infusion fluid
  - < 3.5: 40mmol per litre of infusion fluid **and senior review**

Action 3: Assess response to treatment
- IVII rate may need changing if
  - blood ketones not falling by approx 0.5 mmol/L/hr
  - venous bicarbonate is not rising by at least 3 mmol/L/hr
  - glucose is not falling by at least 3 mmol/L/hr

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ACTION 4: ADDITIONAL MEASURES

- Regular observations and SEWS score
- Naso-gastric tube if patient obtunded or if persistently vomiting
- Accurate fluid balance chart, minimum urine output 0.5ml/kg/hr. Consider urinary catheterisation
- Low molecular weight heparin for thrombo-prophylaxis
- Consider ECG monitoring if potassium abnormal/cardiac concerns
- Do not rely on urinary ketone clearance to indicate resolution of DKA

6 – 12 hours

Action 1: Reassess and monitor vital signs
- Seek senior advice if patient not improving
- Continue IV fluid at a reduced rate
  - 0.9% sodium chloride 1L with KCl: over 4hrs, followed by 6 hours
  - supplement K+ according to Action 2 in Section 60mins to 6 hours.
  - reassess at 12hours, further IV fluids may be required
- If glucose falls below 14 mmol/L commence 10% glucose given at 125mls/hour alongside the 0.9% sodium chloride solution.

Action 2: Review metabolic parameters
- At 6 hours check venous pH, bicarbonate, potassium, as well as blood ketones and glucose

RESOLUTION

- Resolution is defined as ketones less than 0.3mmol/L, venous pH over 7.3 (do not use bicarbonate as a surrogate at this stage)
- If DKA resolved – convert to subcutaneous insulin (see below). If DKA not resolved refer to Action 3 in Section 60mins to 6 hours.

12 – 24 HOURS

The expectation is that ketonaemia and acidosis will have resolved. Request senior review if DKA not resolved.

Action 1: Reassess and monitor vital signs

Action 2: Review metabolic parameters
- At 12 hours check venous pH, bicarbonate, potassium, as well as blood ketones and glucose
- Has DKA resolved (ketones <0.3mmol/L, venous pH >7.3 and/or venous bicarb >18mmol/L)?
- If DKA resolved – convert to subcutaneous insulin.
- If DKA not resolved refer to Action 3 in Section 60mins to 6 hours.

CONVERSION TO SUBCUTANEOUS INSULIN

Convert back to an appropriate subcutaneous regime when ketosis resolved and the patient is able to eat. Conversion to subcutaneous insulin is ideally managed by the Specialist Diabetes Team – involve them if not already done. This also allows re-education and facilitates follow up.

DIABETES TEAM CONTACT DETAILS

Ext 15933 or via switchboard

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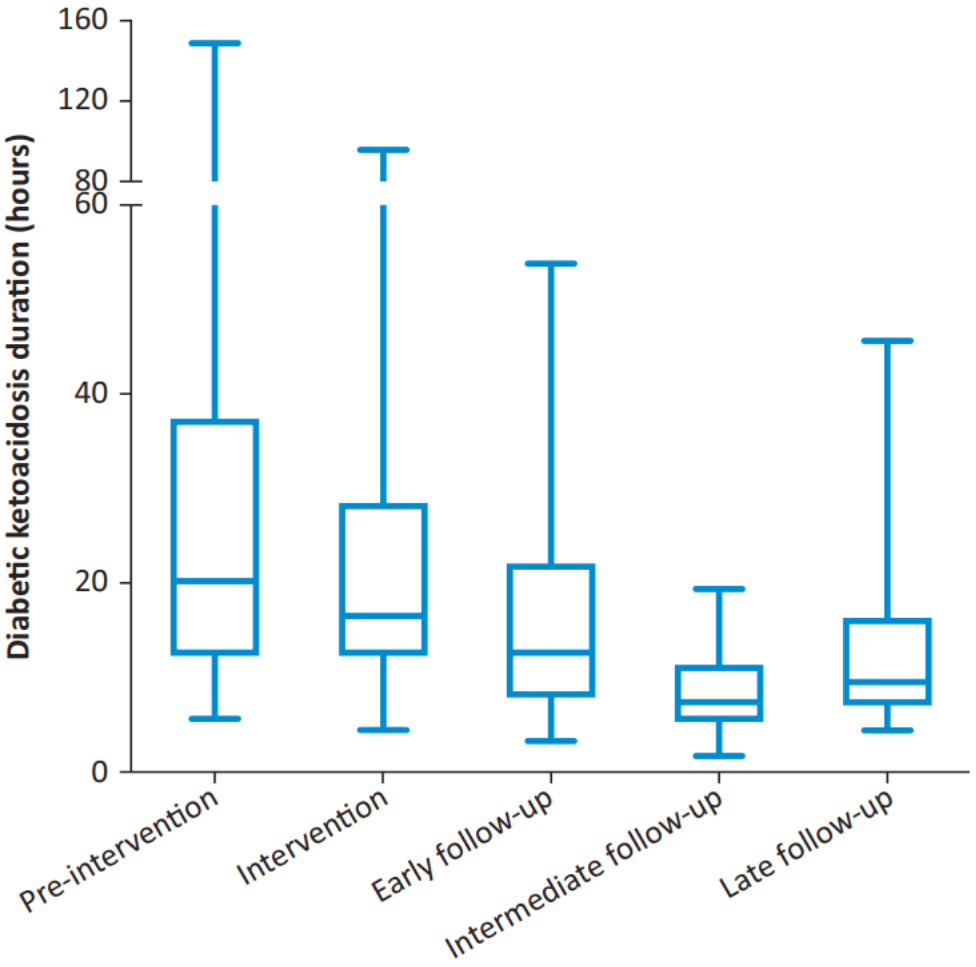

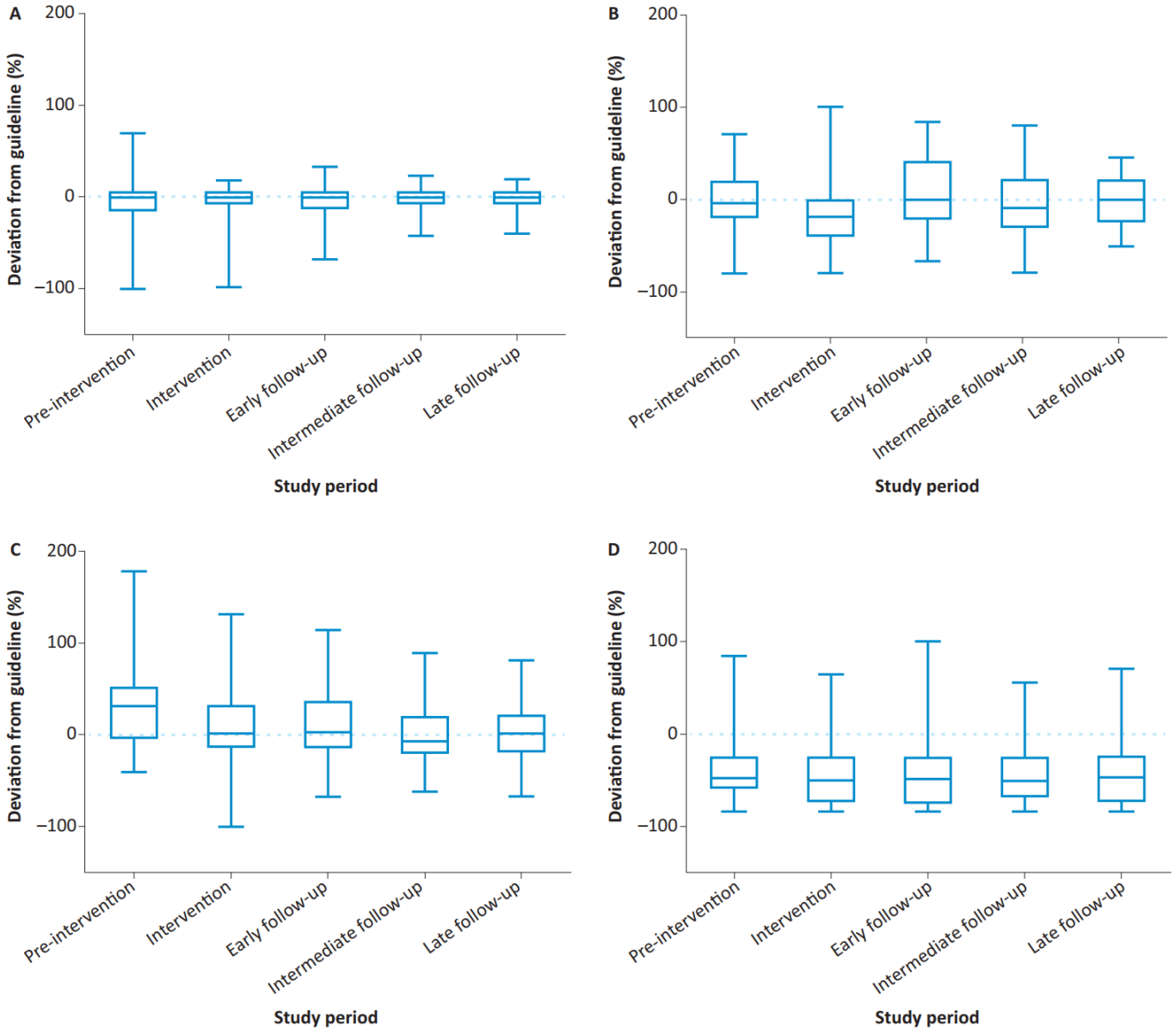

Kempegowda P, et al. Clinical Medicine. 2017

Clinical Medicine 2017 Vol 17, No 5: 389–94

ORIGINAL RESEARCH

Regular and frequent feedback of specific clinical criteria delivers a sustained improvement in the management of diabetic ketoacidosis

Authors: Punith Kempegowda,[A] Ben Coombs,[B] Peter Nightingale,[C] Joht Singh Chandan,[D] Jaffar Al-Sheikhli,[E] Bhavana Shyamanur,[D] Kasun Theivendran,[D] Anitha Vijayan Melapatte,[F] Umesh Salanke,[G] Mohammed Akber,[G] Sandip Ghosh[G] and Parth Narendran[H]

BMJ Open Diab Res Care 2019;**7**:e000695. doi:10.1136/bmjdrc-2019-000695

2017-2018

I moved to another Trust in 2017

Came back in 2018 and was keen to see how things were with DKA

Particularly interested to see if the improvement sustained

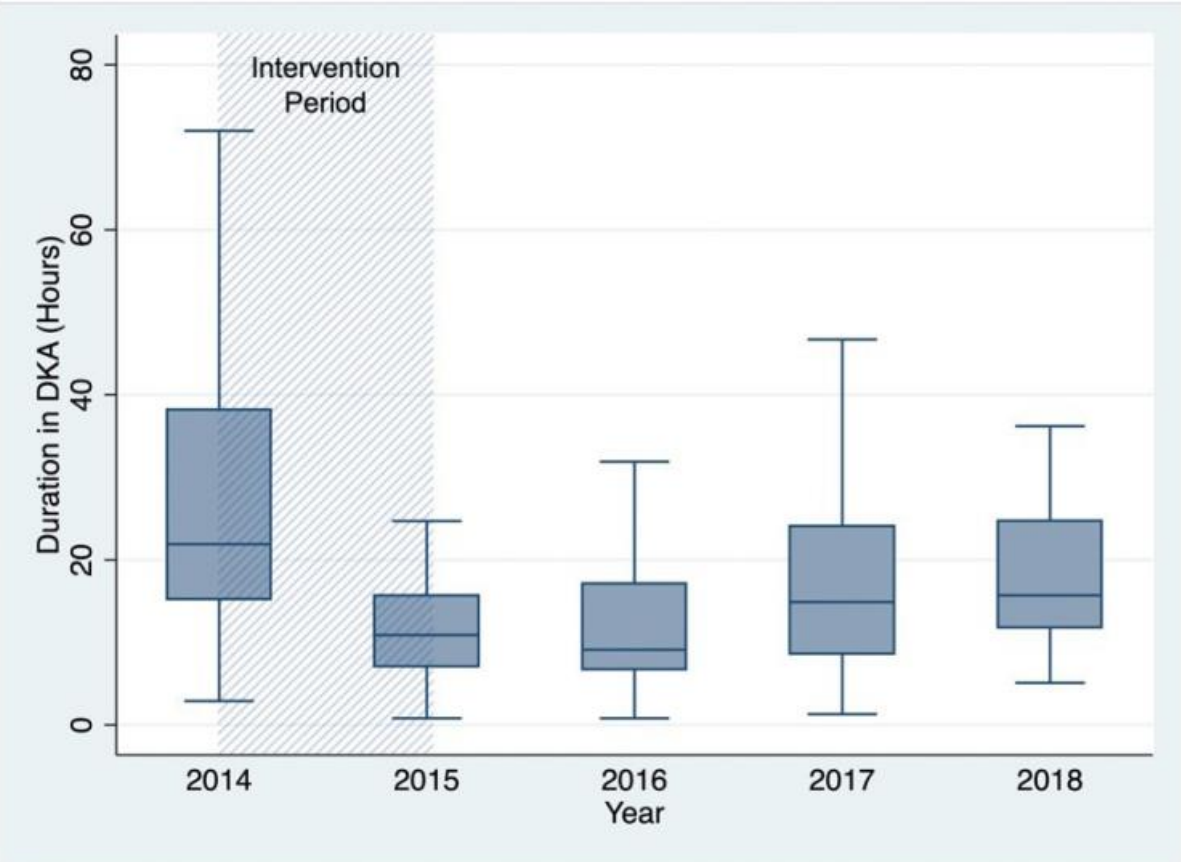

Figure 5 Duration of DKA per year. DKA, diabetic ketoacidosis.

What are the new findings?

- We were able to reduce DKA duration with tailored interventions and sustain the improvement with regular feedback. The trend of DKA duration headed toward baseline in the absence of regular feedback.

How might these results change the clinical practice?

- Incorporating regular feedback to end users may help provide better care to patients with DKA.

Kempegowda P, et al. BMJ Open Diabetes Research and Care. 2019

Management of DKA

A to K & D

- A Airway
- B Breathing
- C Circulation
- D Diabetes
- E Electrolytes and pH
- F Fluid replacement
- G Hourly Glucose
- H HbA1C
- I Fixed rate Insulin
- J Clinical Judgement
- K Hourly Ketones

and

- D Diabetes team referral

Diagnostic criteria

All three of the following should be present:

1. Capillary blood glucose >11mmol/L or history of diabetes † (glucose may be ≦11mmol/L in euglycaemic ketoacidosis)
2. Capillary ketone >3mmol/L or urine ketones >2+.
3. Venous pH <7.3 and/or bicarbonate <15mmol/L.

When to refer to critical care unit

- Young (18-25) or elderly
- Pregnancy
- Heart or liver or kidney failure
- Severe DKA judged by: blood ketones >6 mmol/l, bicarb <5mmol/l, pH <7.1, hypokalaemia, GCS <12, SpO2 <92%, brady/tachycardia or anion gap >16

0-60 minutes

Restore circulating volume
- Give 500ml bolus of 0.9% sodium chloride infusion until systolic BP is >90mmHg
- Once systolic BP >90mmHg, Give 1L of 0.9% sodium chloride over one hour.

Start Insulin therapy:
- Start fixed rate insulin infusion at 0.1ml/kg/hr (prescribed as Actrapid Inf DKA on PICS).
- Continue patient's long acting subcutaneous insulin

Initiate monitoring
- Hourly capillary glucose
- Hourly capillary ketones
- Venous bicarbonate and potassium at 60 minutes, 2hours and 2 hourly thereafter.
- 4 hourly plasma electrolytes

60 minutes to 6 hours

Reassess patient and continue monitoring:
- Hourly blood ketone and glucose monitoring
- Venous gas for pH, bicarbonate and potassium at end of each fluid bag

Continue fluid management:
- 1L 0.9% sodium chloride with potassium*, over 2 hours
- 1L 0.9% sodium chloride with potassium*, over 2 hours
- 1L 0.9% sodium chloride with potassium*, over 4 hours

Assess the patients response
Change Infusion rate if:
- Ketones not falling at 0.5mmol/hr
- Bicarbonate not rising by 3mmol/hr
- Glucose not falling by 3mmol/hr

6 -12 hours

Reassess and monitor vital signs:
- Seek senior medical advice if patient not improving
- If glucose <14mmol/L start 10% glucose at 125mls/hr alongside sodium chloride

Continue fluid management:
- 1L 0.9% sodium chloride with potassium*, over 4 hours
- 1L 0.9% sodium chloride with potassium*, over 6 hours
- Reassess at 12 hours

Review Metabolic Parameters:
- Continue hourly blood ketone and glucose monitoring
- Venous gas for pH, bicarbonate and potassium at end of each fluid bag

12-24 hours

- DKA should have resolved by now
- Reassess and monitor vital signs

Review Metabolic parameters:
- At 12 hours check venous pH, bicarb, potassium, as well as ketones and glucose.
- Check if DKA has resolved. If not seek senior advice.

*Potassium supplementation

This should be according to blood K+ (mmol/L):
- >5.5: No potassium replacement
- 3.5-5.5: 40mmol per litre of infusion fluid
- <3.5: senior review to assess the risks and benefits of replacement

Resolution of DKA

- Resolution is defined as ketones less than 0.6mmol/L and venous pH over 7.3
- If DKA has resolved-
  - convert to s/c insulin if patient eating and drinking well
  - Switch to variable rate intravenous insulin infusion if patient is unwell or unable to eat and drink

† Rule out **Euglycaemic ketoacidosis** and **Hyperglycaemic Hyperosmolar State** (HHS) in high risk acutely unwell patients with diabetes (Eg: Pregnancy, those on SGLT-2 inhibitors (gliflozins)

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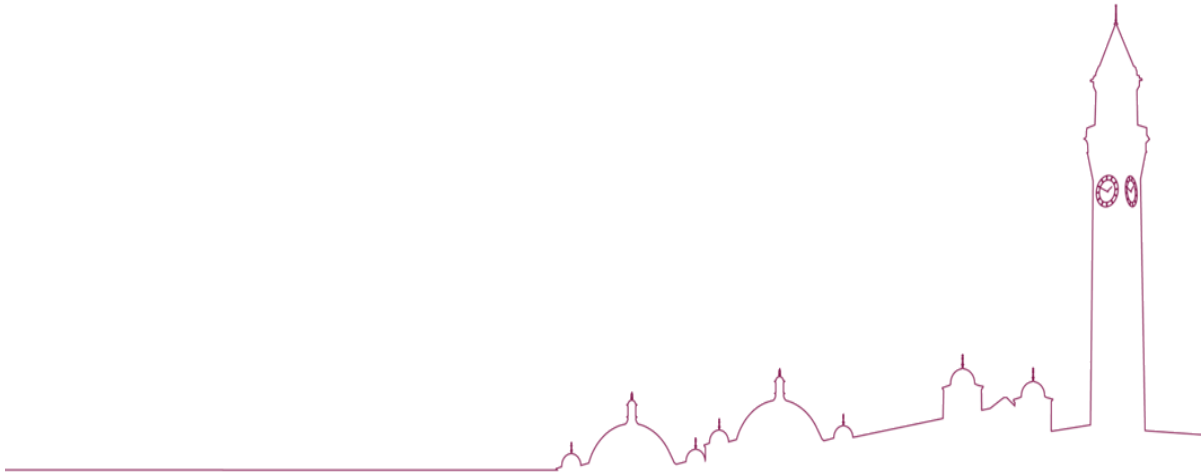
Can QI go beyond improvement?

- We aimed to explore the differences in the demographics, presentation and management of DKA in adults with type 1 and type 2 diabetes
- Impact of age, sex, ethnicity



Flow Chart

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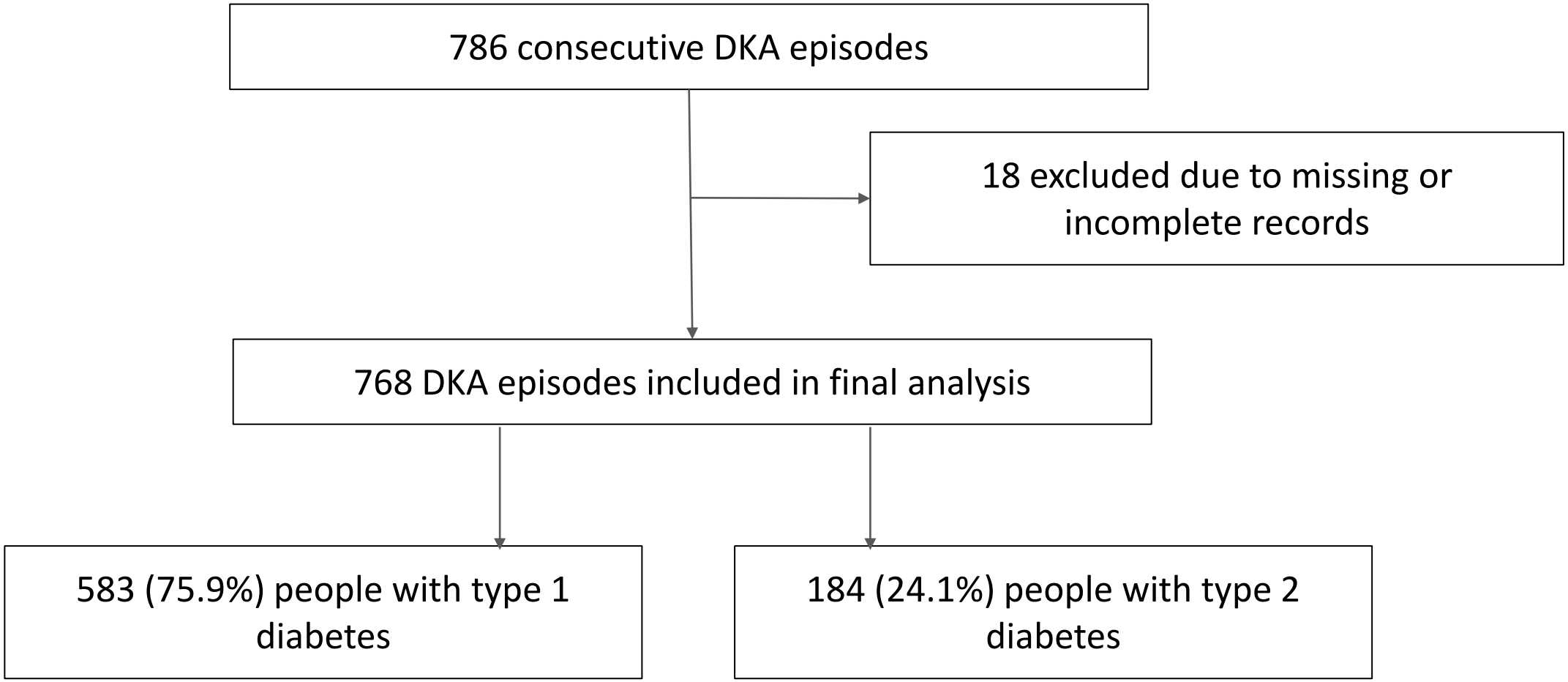

Precipitating Aetiology

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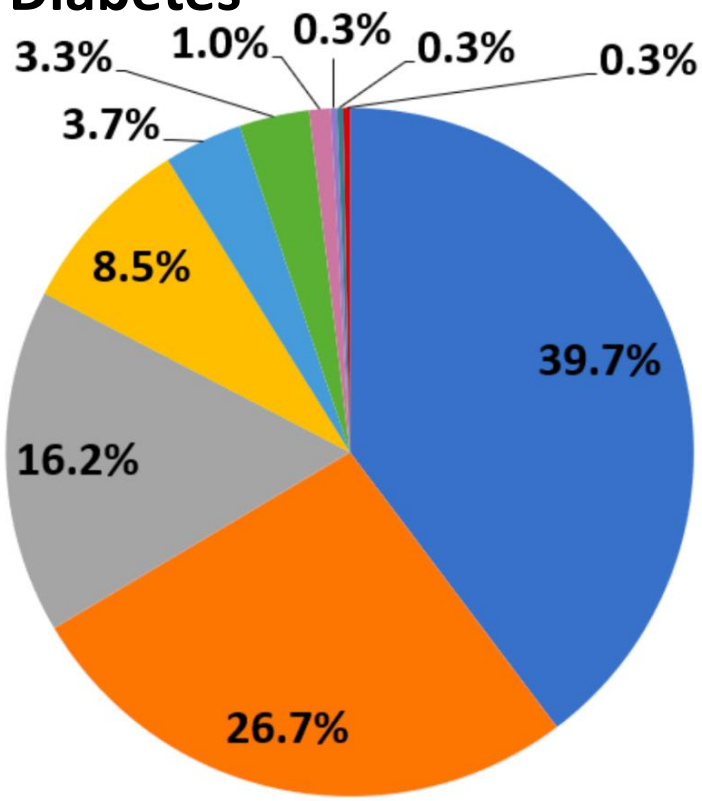
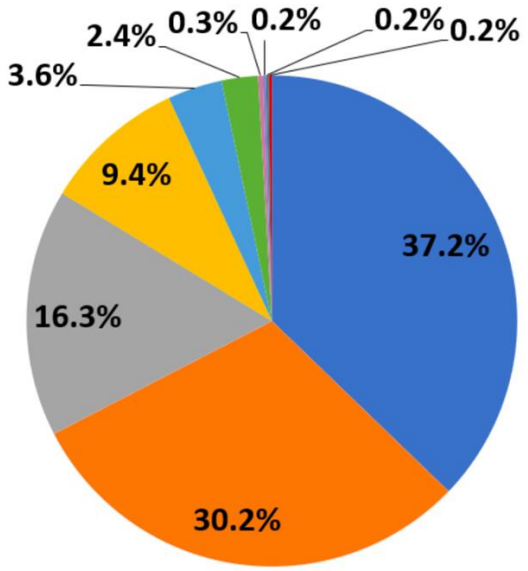
Type 1 and Type 2 Diabetes

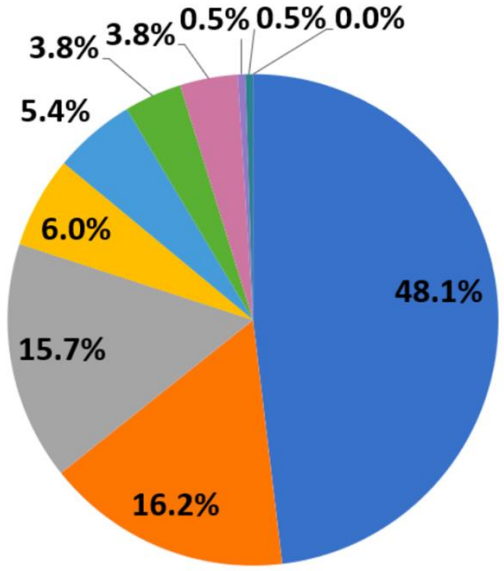


- intercurrent illness
- suboptimal compliance to treatment
- unclear
- surgical
- new diagnosis of T1DM
- alcohol-related
- SGLT2-related
- COVID-19
- drug-induced
- immunotherapy-induced

Type 1 Diabetes



Type 2 Diabetes



Precipitating Aetiology by Year

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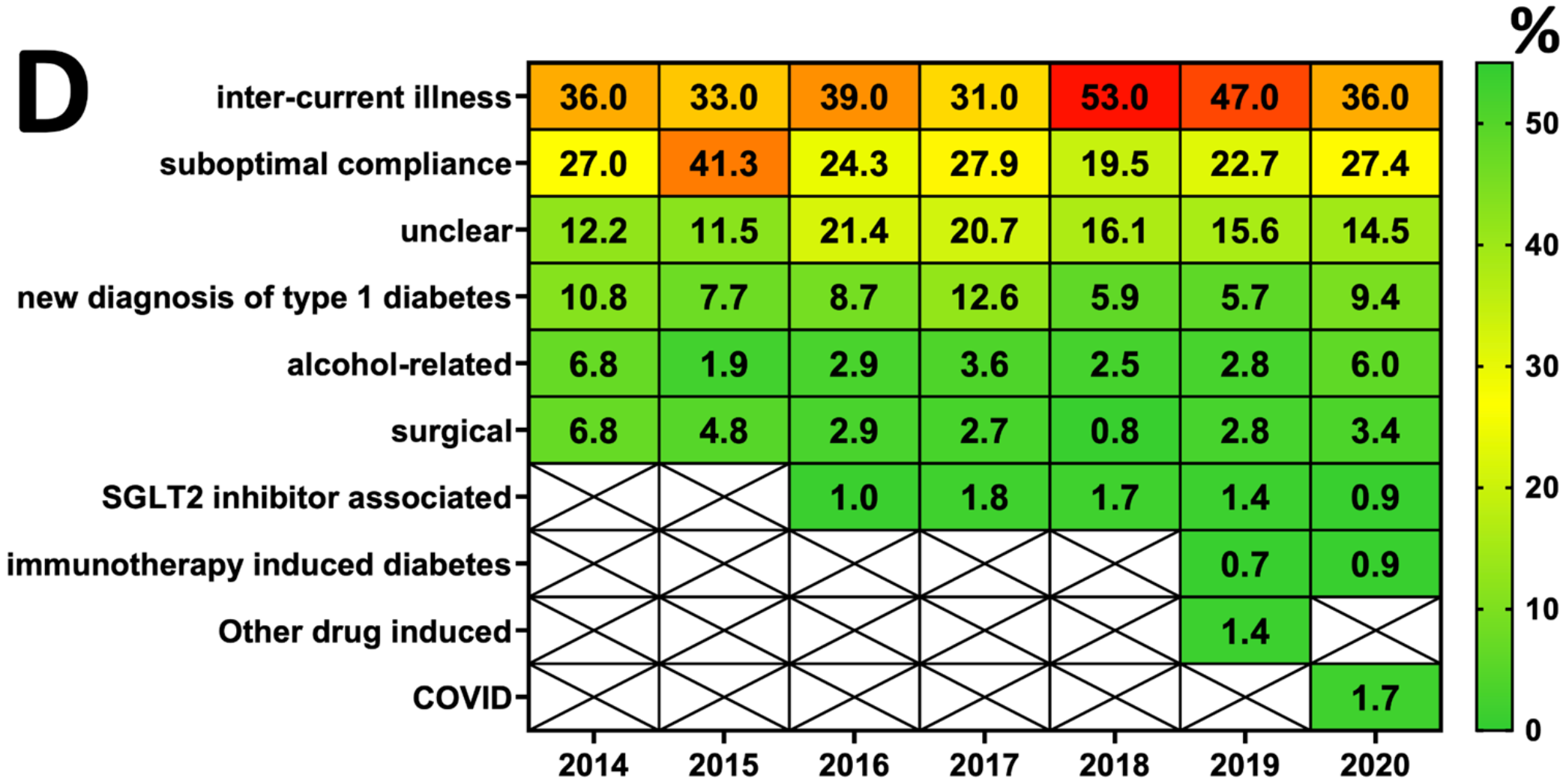

Outcome of DKA

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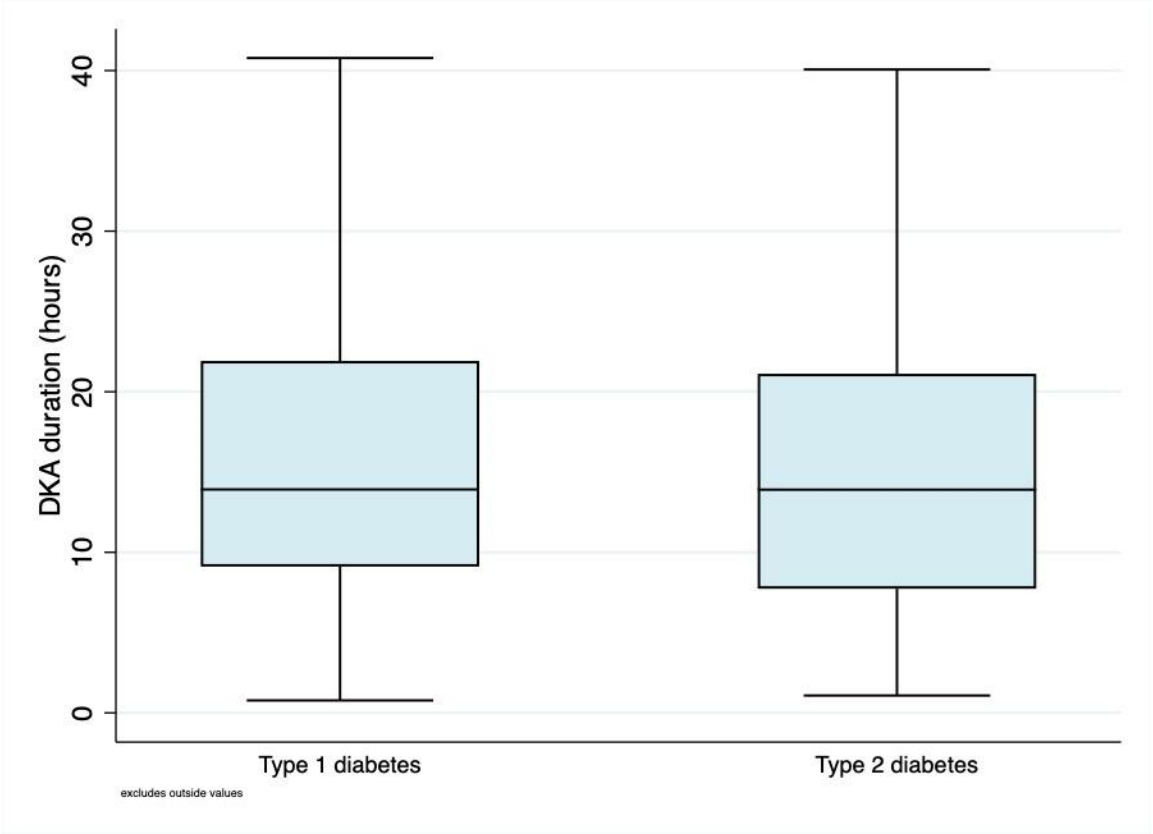
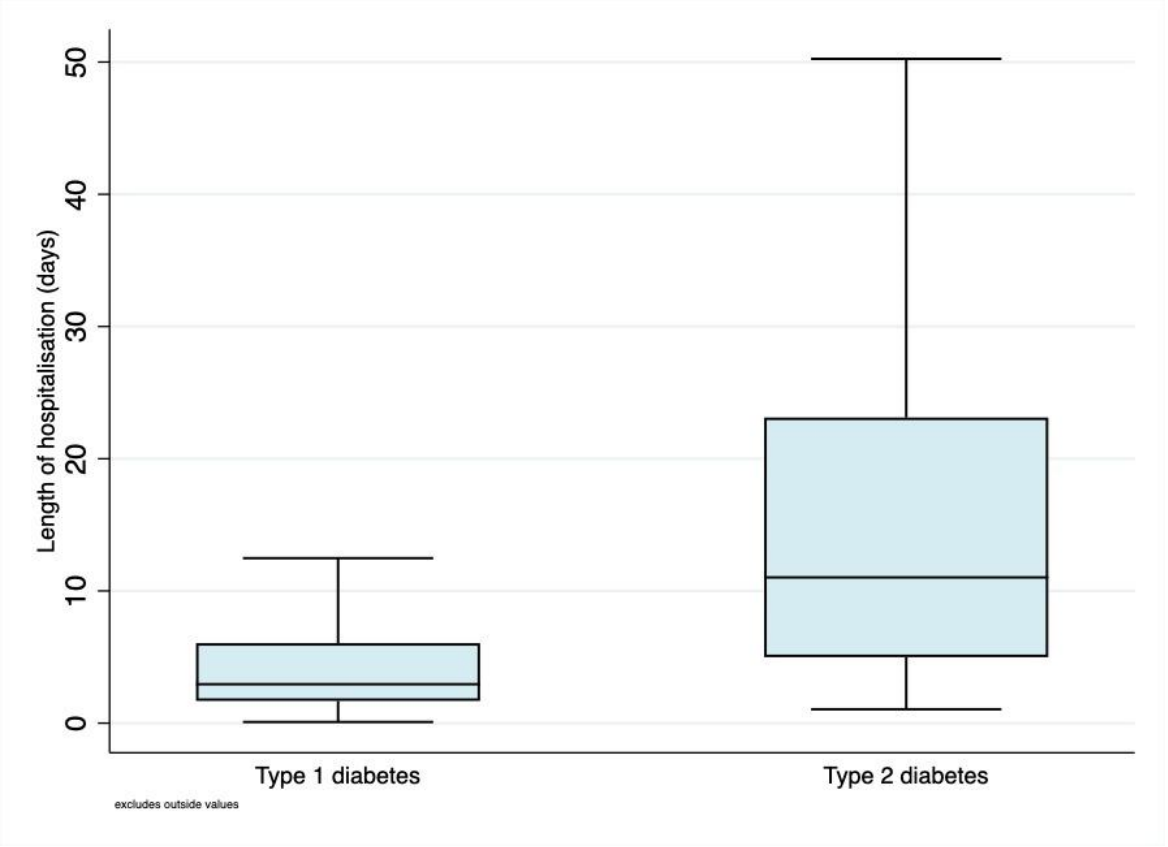
DKA duration



Length of hospitalisation



Age and sex-based differences

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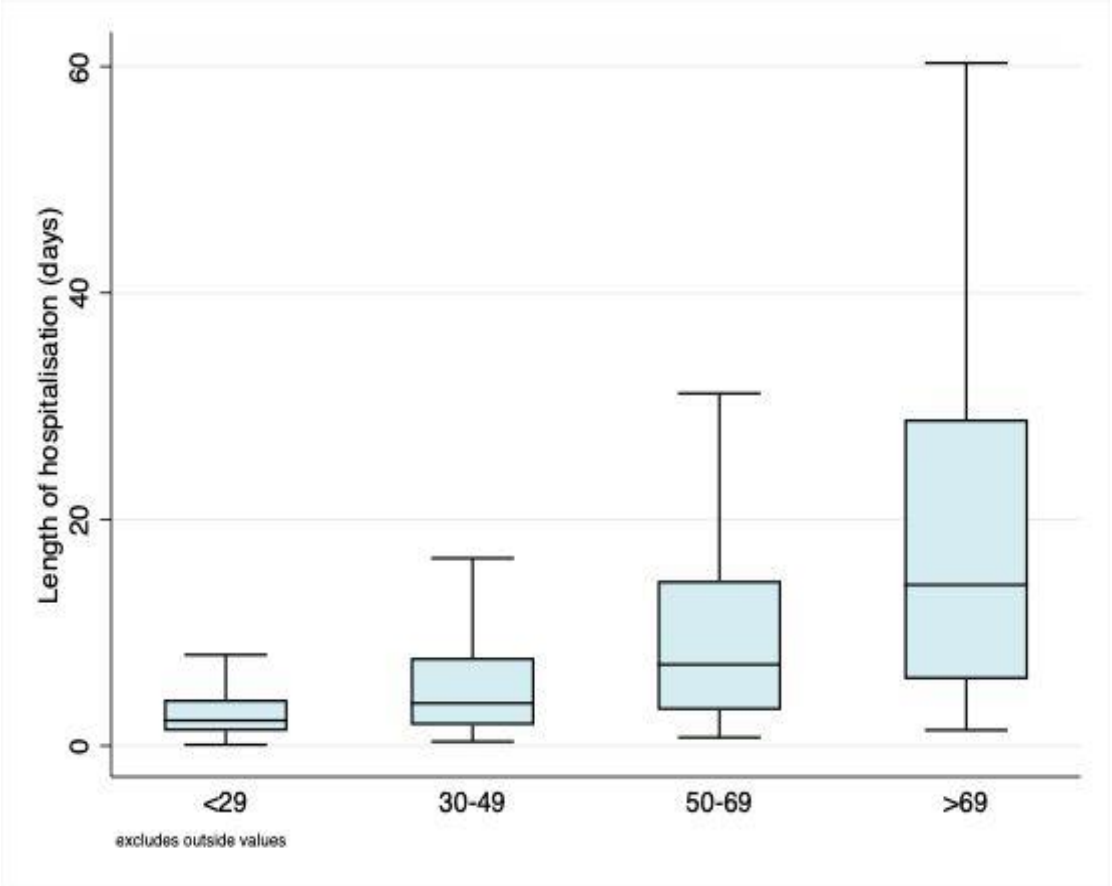
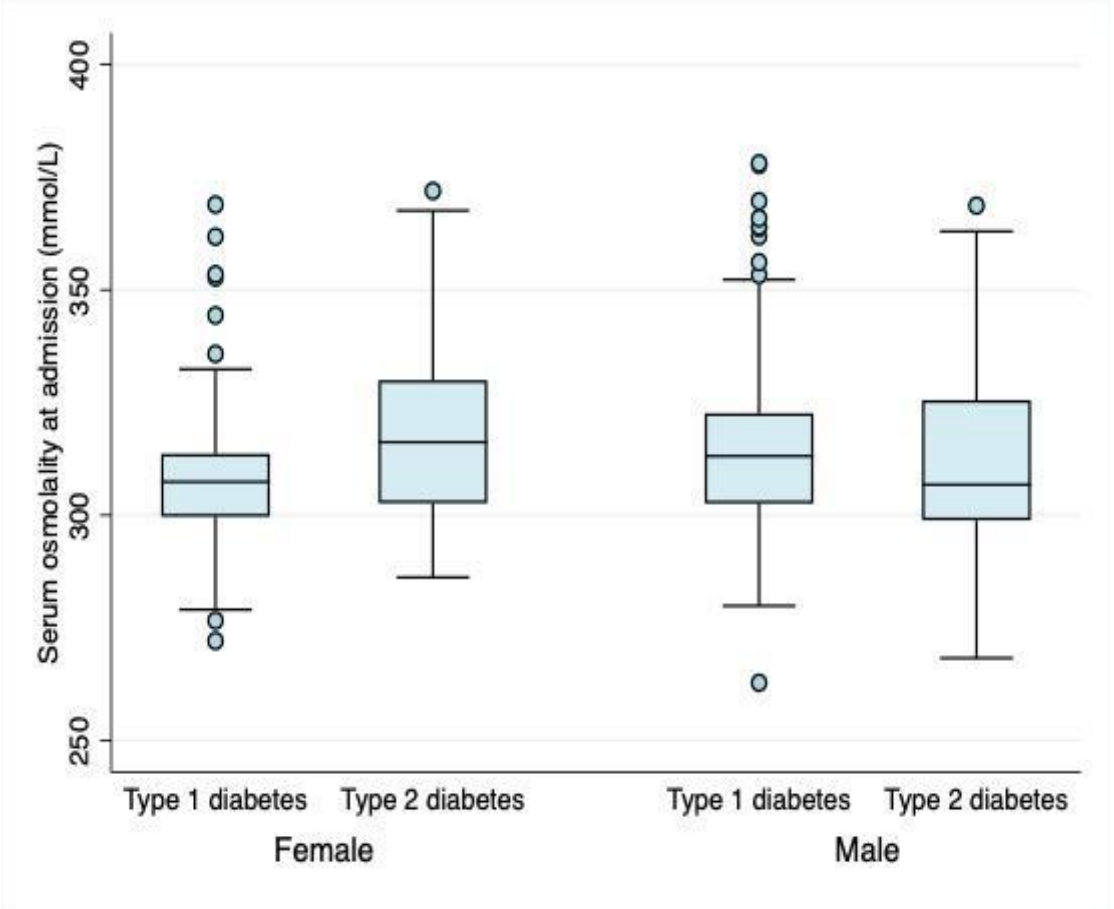




BMJ Open Diabetes Research & Care

Clinical and biochemical profile of 786 sequential episodes of diabetic ketoacidosis in adults with type 1 and type 2 diabetes mellitus

Emma Ooi ,[1] Katrina Nash,[2] Lakshmi Rengarajan,[3] Eka Melson,[3,4] Lucretia Thomas,[2] Agnes Johnson,[2] Dengyi Zhou,[2] Lucy Wallett,[3] Sandip Ghosh,[3] Parth Narendran,[3,5] Punith Kempegowda[3,4]

To cite: Ooi E, Nash K, Rengarajan L, *et al*. Clinical and biochemical profile of 786 sequential episodes of diabetic ketoacidosis in adults with type 1 and type 2 diabetes mellitus. *BMJ Open Diab Res Care* 2021;**9**:e002451. doi:10.1136/bmjdrc-2021-002451

► Additional supplemental material is published online only. To view, please visit the journal online (http://dx.doi.org/10.1136/bmjdrc-2021-002451).

ABSTRACT

Introduction We explored the clinical and biochemical differences in demographics, presentation and management of diabetic ketoacidosis (DKA) in adults with type 1 and type 2 diabetes.

Research design and methods This observational study included all episodes of DKA from April 2014 to September 2020 in a UK tertiary care hospital. Data were collected on diabetes type, demographics, biochemical and clinical features at presentation, and DKA management.

Results From 786 consecutive DKA, 583 (75.9%) type 1 diabetes and 185 (24.1%) type 2 diabetes episodes were included in the final analysis. Those with type 2 diabetes were older and had more ethnic minority representation than those with type 1 diabetes. Intercurrent illness (39.8%) and suboptimal compliance (26.8%) were the

Significance of this study

What is already known about this subject?

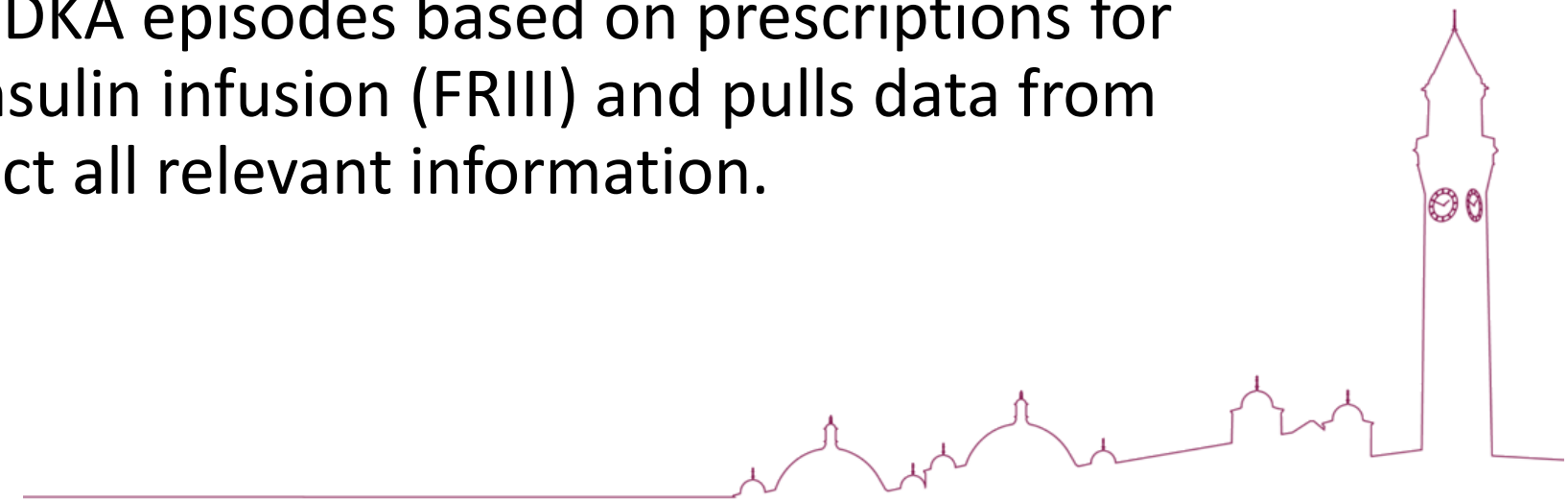
- Diabetic ketoacidosis (DKA) is generally associated with type 1 diabetes mellitus (T1DM) but can also develop in people with type 2 diabetes mellitus (T2DM).
- Common precipitants of DKA in T1DM and T2DM are intercurrent illness and suboptimal treatment.
- DKA in people with T1DM and T2DM are currently managed using the same clinical protocols.

What are the new findings?

- DKA in those with T2DM is more common in people of ethnic minority background.

Let's share best practices

- We were then interested to see if this can be adapted to other centres as well
- Reduce duplication of work, bring in uniformity in data collection
- A system that identifies DKA episodes based on prescriptions for fixed rate intravenous insulin infusion (FRIII) and pulls data from electronic notes to collect all relevant information.



Digital Evaluation of Ketosis and Other Diabetes Emergencies (DEKODE)

Simplifying

A registry for DKA across various centres allows uniform data storage

Centralising

analysis limits time gap between data collection and intervention

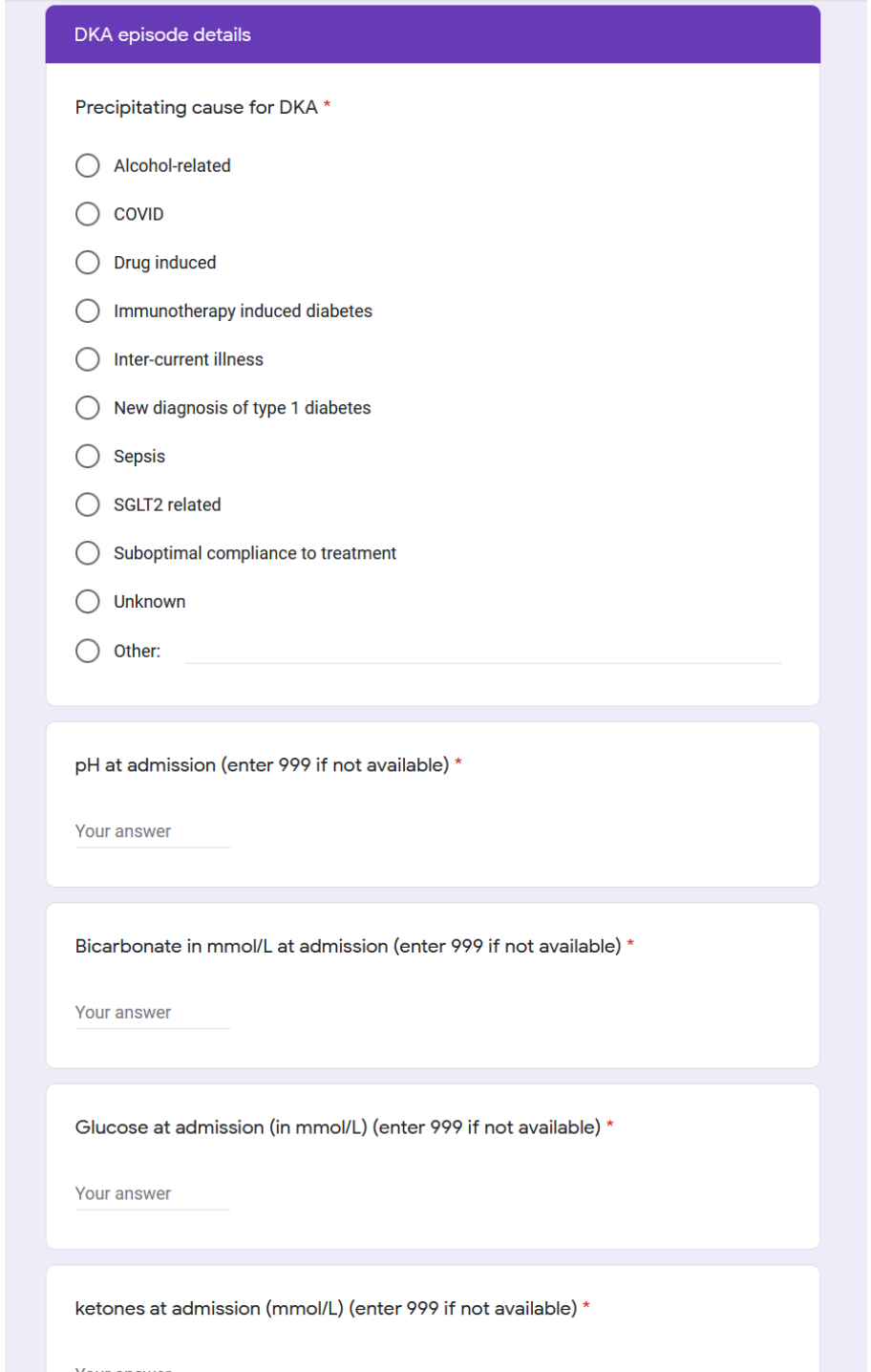
Learning

Learning from each others' best practices

University Hospitals Birmingham
NHS Foundation Trust

Walsall Hospitals
NHS Trust

Sandwell and West Birmingham
NHS Trust


DKA episode details

Precipitating cause for DKA *

- Alcohol-related
- COVID
- Drug induced
- Immunotherapy induced diabetes
- Inter-current illness
- New diagnosis of type 1 diabetes
- Sepsis
- SGLT2 related
- Suboptimal compliance to treatment
- Unknown
- Other:

pH at admission (enter 999 if not available) *

Your answer

Bicarbonate in mmol/L at admission (enter 999 if not available) *

Your answer

Glucose at admission (in mmol/L) (enter 999 if not available) *

Your answer

ketones at admission (mmol/L) (enter 999 if not available) *

Methods (continued)

- Each admission was assigned a unique code (Eg: SWBH-001, QEHB-0001) for pseudonymised data collection
- Use of pre-approved data collection tool
- Analysed using SPSS version 27.0
- Independent-Samples Kruskal-Wallis Test

Methods continued

- Year of birth
- Gender
- Ethnicity
- Type of diabetes
- Weight
- Height
- Previous insulin treatment – form and dose
- Other diabetes medications
- Admission and discharge date and time
- Precipitating cause for DKA
- pH, bicarbonate, glucose, ketones, lactate at admission
- Sodium, potassium, urea at admission
- Date and time of DKA diagnosis
- Date and time of DKA resolution
- Rate of fixed rate insulin
- Details of glucose measurements between DKA diagnosis and resolution
- Details of ketone measurements between diagnosis and resolution
- Details of potassium monitoring between diagnosis and resolution

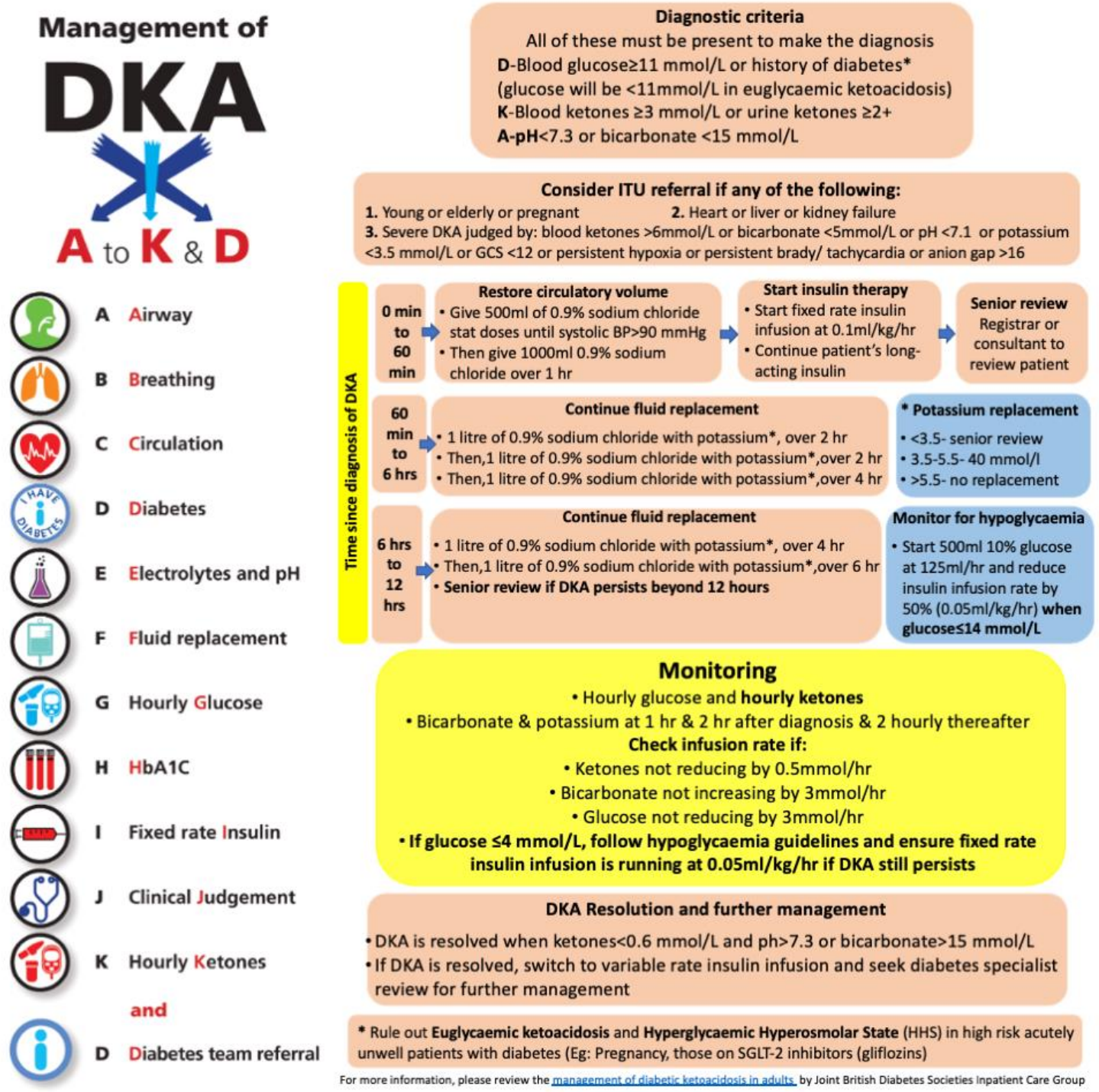
+ whether the following were done during the inpatient episode:

- ECG
- Urine MSU
- ITU referral
- ITU admission
- Basal insulin continued alongside fixed rate
- Management in a monitored bed
- Fluid balance maintained
- 10% dextrose started when blood glucose <14mmol/L
- Specialist review by diabetes team
- Follow up with diabetes team arranged after discharge
- VTE prophylaxis during DKA

Results

switching to excel to show some fresh off the oven outcome measures

- Current version of guidelines incorporated into all participating hospitals in DEKODE



NHS
University Hospitals Birmingham
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Did you know?

There's been a change in the Diabetic Ketoacidosis (DKA) guidelines!

UHB and (JBDS) Update:

(1) once blood glucose levels reach ≤14mmol/l (1).

(2) reduce the insulin infusion rate from 0.1 units/kg/hr to 0.05 units/kg/hr

(3) This is alongside 10% glucose 125ml/hr administration

This would decrease the incidence of hypoglycaemia and hypokalaemia

Discussion

Uniform data collection is possible across multiple sites and hospitals without breaching information governance regulations.

Each centre excel is some but not all aspects of DKA management, suggesting there is scope to share best practices between the centres.

Information is powerful and letting people see data will change behaviour

Getting medical students and junior doctors involved has helped them get more insight into QIP and D&E, which has translated into better HCPs and hoepfully future leaders in our speciality

Future directions

Invite more hospitals into the DKA Registry, in order to continue to learn from each other
Innovative interventions to improve the understanding of the pathophysiology and management of DKA- #CoMICs
Implement feedback system in each centre
Implement best practices from other centres in each hospital

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- Ben Coombs
- Bhavana Shyamanur
- Catherine Cooper
- Eka Melson
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- Kasun Theivendran
- Lakshmi Rengarajan
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- Nitesh Jawahar
- Sunil James
- Shamath Soghal

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INSTITUTE OF IMMUNOLOGY AND IMMUNOTHERAPY

ABCD Association of British Clinical Diabetologists

NHS University Hospitals Birmingham NHS Foundation Trust

Walsall Hospitals NHS NHS Trust

NHS Sandwell and West Birmingham NHS Trust

JBDS-IP Joint British Diabetes Societies for inpatient care