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Protocolised inpatient care of diabetes mellitus

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ABSTRACT

Background: The prevalence of hyperglycaemia in patients with diabetes mellitus at admission is high. Prevention and treatment is important to prevent further clinical complications. We have conducted a study evaluating implementation of a new protocol to standardise inpatient care of patients with diabetes mellitus.

Methods: A retrospective study including all glucose measurements of adult patients with diabetes mellitus type 1 or 2, admitted to a surgery department, was performed before and after implementation of the new protocol. This protocol included direct consultation of an internist and diabetes specialist nurse at admission, who initiated a daily treatment program and adjustment scheme based on glucose measurements four times a day by the HemoCue201DM glucose point of care device. We compared the prevalence of hyperglycaemia and hypoglycaemia before and after implementation with logistic regression analyses adjusted for age and gender.

Results: Overall, 360 patients with diabetes mellitus type 1 or 2 with 5322 glucose measurements were included. The risk of developing hyperglycaemia was significantly reduced after implementation of the protocol (22 patients with 65 hyperglycaemias) compared with before the intervention (70 patients with 417 hyperglycaemias) (RR adjusted 0.24 (95% confidence interval 0.19; 0.32)). Overall, 45 patients experienced 95 episodes of hypoglycaemia, which did not differ significantly between the two groups.

Conclusion: After implementation of a new protocol to standardise inpatient care of diabetes mellitus we established a decrease in the risk to develop hyperglycaemia of 76% without an increased risk of developing hypoglycaemia. Implementation of this protocol required frequent glucose measurements which are facilitated by point of care glucose measurements.

KEYWORDS

Diabetes mellitus, hyperglycaemia, hypoglycaemia, inpatient care

INTRODUCTION

Diabetes mellitus is a major public health issue with a total prevalence of 14% in 2010 rising to an expected 21% of the USA adult population by 2050.[1] Approximately 10% of all patients who are admitted in an acute setting have diabetes mellitus.[2] The regulation of diabetes mellitus is often disturbed in hospital due to, for instance, the use of several drugs, infection, altered eating patterns or decreased mobilisation.

Hyperglycaemia due to decompensated diabetes mellitus, unrecognised diabetes mellitus or hospital-related hyperglycaemia leads to increased morbidity and mortality, mainly due to an increase in infections due to immunosuppression, cardiovascular events, venous thromboembolic events, inflammation, endothelial cell dysfunction and cerebral ischaemia.[3] Therefore, it is important to treat and prevent hyperglycaemia.

Recently, we implemented a new protocol to standardise inpatient care of patients with diabetes mellitus, which included a direct consultation of an internist and diabetes specialist nurse at the admission of patients with diabetes mellitus type 1 or 2, irrespective of the reason for admission. In addition to a daily treatment program, the attending nurse could adjust the insulin dose using a standardised adjustment scheme based on point of care glucose measurements available on each department. Implementation of intensive diabetes mellitus therapy requires frequent and accurate blood glucose data. Glucose monitoring using capillary blood has an advantage over

laboratory venous glucose testing since the results can be obtained rapidly at the 'point of care'.[3] Glucose results were monitored by a point of care testing (POCT) device, whose performance appeared to be in accordance with the guidelines for decentralised monitoring of glucose.[4]

We have conducted a retrospective study in the Maasstad Hospital in Rotterdam comparing the prevalence of hyperglycaemia and hypoglycaemia before and after implementation of this new protocol.

METHODS

Setting and study design

The study population comprised all patients of 18 years and older with diabetes mellitus type 1 or 2 using oral antidiabetics and/ or insulin therapy admitted to one of the surgery departments of the Maasstad Hospital in Rotterdam.

A retrospective study was conducted comparing all glucose measurements after implementation of the inpatient care of diabetes mellitus protocol (September and October 2010) with all glucose measurements before implementation (March, April and May 2010). All glucose measurements during admission were included. Overall, there were 409 patients with 5466 glucose measurements. We excluded patients (n=49; 144 glucose measurements) who were not referred to the internist or diabetes specialist nurse by the attending nurse of the department where the patient was admitted.

Age on the day of the glucose measurement, gender and department were retrieved from the computer-based healthcare information system.

Glucose measurements

At admission, glucose concentration was measured by the laboratory reference method. The protocol included direct consultation of an internist and diabetic specialist nurse at admission, who initiated a daily treatment program. Glucose measurements were monitored four times per day with POCT devices available on each department. The values are present within seconds and are automatically registered in the computer-based healthcare information system. In the Maasstad Hospital, the HemoCue Glucose 201DM device (201DM) was used, which has recently been compared with a new generation device (201DMRT).[4] This comparison showed a high correlation coefficient of 0.998 and acceptable total measurement error (total error <10% in the concentration range 4-20 mmol/l). Moreover, the method correlated well with the reference laboratory method. It is generally accepted that the hexokinase glucose method is the reference method for glucose measurement. Recently, an excellent agreement between the HemoCue Glucose 201DMRT device and the Vista hexokinase reference method within the measured range was found (2-30 mmol/l). The results were not influenced by changes in partial oxygen pressure, although they were influenced by changes in haematocrit in a predictable fashion.[4]

Glucose measurements below 4 mmol/l were defined as hypoglycaemia and measurements more than 15 mmol/l were defined as hyperglycaemia.

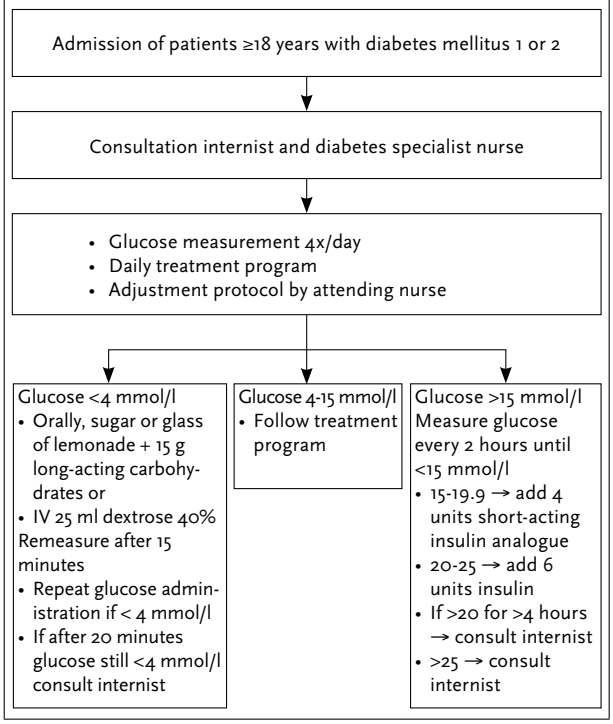
Intervention

In September 2010, a new protocol was implemented to standardise the treatment of patients with diabetes mellitus in the inpatient clinic. The implementation was started in the surgery departments and later on extended to all departments. Before implementation all nurses from the surgery departments were trained.

Before implementation of the protocol, patients used their own dosage of oral antidiabetic drugs or insulin. The primary caregiver could consult the internist when patients experienced hypo- or hyperglycaemia or when the patient's intake had to be altered (e.g. fasting, fluid diet).

After implementation of the protocol (*figure 1*), the attending nurse of the department set up a direct consultation with the internist and diabetes specialist nurse. The diabetes specialist nurse and the internist agreed on a daily treatment program based on the previous treatment dosages, reason for admission, intake and mobilisation and current glucose measurements,

Figure 1. *Inpatient care of diabetes mellitus*



pursuing a glucose target value of 4-10 mmol/l. Glucose was measured four times a day (preprandial and before bedtime). In addition, the insulin dosage could be adjusted by the attending nurse according to the glucose measurement using the protocol when glucose measurements were <4 or >15 mmol/l (*figure 1*). The diabetes nurse contacted the attending nurse on a daily basis and changed the treatment program if necessary, under supervision of the internist.

Statistical analysis

The baseline characteristics before and after the intervention were compared using the t-test as well as the number of episodes of hyperglycaemia and hypoglycaemia overall and within one patient.

Linear regression was used to calculate the difference in glucose level after the intervention compared with before the intervention. The relative risk with 95% confidence interval of hyperglycaemia or hypoglycaemia in the group of patients after the intervention was implemented was compared with the group of patients before implementation of the intervention. This was estimated by calculation of the unadjusted and adjusted (for age and gender) odds ratios using univariate and multivariate logistic regression analyses. In addition, in a sensitivity analysis, patients with >20 episodes of hyperglycaemia and hypoglycaemia were excluded to eliminate the possibility that a few patients with a lot of episodes of hyperglycaemia altered the risk estimate. All analyses were performed using SPSS for Windows version 18.0.

RESULTS

Patient characteristics

Overall, 360 patients with diabetes mellitus type 1 or 2 with 5322 glucose measurements were included during the study period (*tables 1* and *2*). Of all patients, 47.8% were male, which did not differ significantly between the two groups. The group of patients included after the intervention was slightly younger, although not significantly different from the group before the intervention.

Complications

Overall, 45 patients experienced 95 hypoglycaemia episodes. There was no significant difference in the prevalence of hypoglycaemia between the two groups (*table 2*). In contrast, significantly less patients experienced hyperglycaemia after implementation of the intervention (22 patients with 65 hyperglycaemias) compared with before the intervention (70 patients with 417 hyperglycaemias). After adjustment for age and gender, there was a 76% (relative risk (RR) 0.24 (95% CI 0.19; 0.32)) risk reduction to develop hyperglycaemia (*table 3*). This risk was still significantly lower after excluding two patients with >20 hyperglycaemias in the group of patients before the intervention (RR 0.30 (95%CI 0.23; 0.40)). Both patients experienced 46 episodes of hyperglycaemias and hypoglycaemias in total. One patient was admitted due

Table 1. *Baseline characteristics*

	Before intervention (March – May 2010) n (%)	After intervention (September – October 2010) n (%)
Number of patients	249	111
Gender (male)	123 (49.4%)	49 (44.1%)
Age (mean (SD) / range in years)	74.8 (16.1)/ 24.8 – 99.6	68.9 (16.2)/ 25.0 – 93.9
Department:		
• Abdominal surgery (1)	78 (31.3%)	32 (28.8%)
• Abdominal surgery (2)	55 (22.1%)	28 (25.2%)
• Trauma surgery	52 (20.9%)	22 (19.8%)
• Vascular surgery	64 (25.7%)	29 (26.1%)

Table 2. *Number of episodes of hyperglycaemia and hypoglycaemia*

	Before intervention (March to May 2010) n (%)	After intervention (September to October 2010) n (%)
Number of patients	249	111
Number of glucose measurements	3373	1949
Number of hyper- and hypoglycaemias	472 (14.0%)*	105 (5.4%)*
- Hypoglycaemia(<4 mmol/l)	55 (1.6%)	40 (2.1%)
- Hyperglycaemia(>15 mmol/l)	417 (12.4%)*	65 (3.3%)*
Number of patients with hyper- and hypoglycaemias		
- Hypoglycaemia(< 4 mmol/l)	29 (11.6%)	16 (14.4%)
- Hyperglycaemia(>15 mmol/l)	70 (28.1%)*	22 (19.8%)*
Number of hyper- and hypoglycaemias within one patient		
- 1	45 (1.3%)	20 (1.0%)
- 2-4	25 (0.7%)	10 (0.5%)
- 5-9	13 (0.4%)	6 (0.3%)
- 10-19	14 (0.4%)	2 (0.1%)
- ≥20	2 (0.1%)	0
Glucose (median/ 25-75 interquartile range in mmol/l)	9.4/7.4-12.4*	8.5 / 7.0-10.5*
Glucose (in mmol/l) after intervention compared with before intervention	Reference	-1.3 (-1.5; -1.1)*

***P<0.0001.**

Table 3. *Risk of hyperglycaemia and hypoglycaemia*

	Before intervention	After intervention	Risk of hyper- and hypoglycaemias (95% CI)	Risk of hyper- and hypoglycaemias adjusted for age and gender (95% CI)
Number of glucose measurements	3373	1949		
- Normoglycaemia	2901	1844	Reference	Reference
- Hypoglycaemia	55	40	1.14 (0.76; 1.73)	1.24 (0.82; 1.88)
- Hyperglycaemia	417	65	0.25 (0.19; 0.32)*	0.24 (0.19; 0.32)*
Sensitivity analysis				
Number of glucose measurements	3080	1860		
- Normoglycaemia	2700	1755	Reference	Reference
- Hypoglycaemia	51	40	1.21 (0.79; 1.83)	1.36 (0.89; 2.07)
- Hyperglycaemia	329	65	0.30 (0.23; 0.40)*	0.30 (0.23; 0.40)*

Sensitivity analysis: exclusion of two patients with >20 hyper- and hypoglycaemias each; *P<0.0001; CI = confidence interval.

to a necrotectomy of the right hallux. The other patient was admitted for gastric perforation. This patient chose to refrain from further treatment due to his comorbidities.

DISCUSSION

In this retrospective study concerning inpatient care of diabetes mellitus, we found a significant greatly decreased risk of developing hyperglycaemia during admission without an increased risk of developing hypoglycaemia after implementation of a new protocol. This protocol included direct consultation of an internist and diabetes specialist nurse at admission, who initiated a daily treatment program. In addition, the attending nurse could adjust the insulin dose using an adjustment scheme based on point of care glucose measurements. The insulin intervention and dose adjustment was performed based on decentralised glucose measurement by a POCT device. Compared with our study, in Atlanta, USA, a higher prevalence of hyperglycaemia was present in 38% of patients at or during admission.[5] In our study approximately 28% of patients with hyperglycaemia before implementation of the intervention versus approximately 20% after implementation was found. This is probably due to the fact that other definitions of hyperglycaemia were used and possibly due to another patient population. In Atlanta, a fasting glucose >7 mmol/l or a non-fasting glucose >11.1 mmol/l were used to determine hyperglycaemia. The group of patients with new hyperglycaemia had a longer length of hospital stay and an 18-fold increased mortality rate compared with the normoglycaemia group.[5]

A number of studies have shown that inpatient care by a multidisciplinary team including a diabetes specialist nurse can reduce the length of stay in hospital without increased readmission rates.[6-9] Consultation of a diabetes team instead of an endocrinologist or an internist alone resulted in 35% and 56% decreased lengths of stay, respectively. Delayed consultation was associated with an increased length of stay.[7] A randomised study comparing consulting a diabetes team and usual care showed a reduction in length of stay from 7.5 to 5.5 days for patients who were admitted because of diabetes mellitus as a primary diagnosis. In patients with another reason for admission with diabetes mellitus as comorbidity, there was no reduction in length of stay; however, a decrease of readmissions in the following three months of 55% was shown.[6] Another randomised study with or without the intervention of a diabetes specialist nurse showed a reduced length of stay (11 versus 8 days). The majority of patients were admitted for reasons unrelated to their diabetes mellitus. Readmission rates were similar in both groups.[9]

The decrease in prevalence of hyperglycaemias in our study did not lead to an increase of hypoglycaemias. Hypoglycaemias have been associated with increased mortality.[10,11] However in a large study it was shown that hypoglycaemia was not an independent predictor for mortality, implying that it is only a marker of poor health.[12]

The strengths of this study are the fact that there is no selection bias, since we included all consecutive patients from the same departments before and after the intervention. We assume a random distribution of the reasons for admission in both groups. We selected a period directly after implementation of the protocol and compared it with a period before the summer in the same year. We excluded a small group of patients who were mistakenly not signed up by the diabetes specialist nurse and internist since this group did not receive the intervention. The relative risk is, however, still significant if we include these patients (p<0.0001, data not shown). In addition, there is no information bias, since all measurements during admission were included; they were retrieved from the computer-based healthcare information system.

Furthermore, one of the strengths of this study was the use of a POCT device, which fulfils the criteria needed for safe point of care testing of glucose. Most of the studies validating performance of POCT devices do not address all issues important for safe measurement of glucose or were not performed according to strict criteria on total error. POCT glucose devices were primarily not

designed to be used for the purpose of monitoring and adjustment of insulin dosing schedules as the quality of their performance was far behind the laboratory reference method. The POCT device used in this study was extensively validated according to strict international criteria. The device used showed a very good correlation with the reference method and with the newest generation of device. Moreover, the total error was acceptable for the measuring range acquired. This made it possible to obtain glucose measurements at the 'point of care' and makes the results of this study very valuable. This device showed that the results of the glucose measurements are not influenced by changes in partial oxygen pressure, although they are influenced by changes in haematocrit in a predictable fashion.[4] This implicates a limitation of this study because we did not correct the glucose measurements for haematocrit, since this is difficult to implement in daily practice. However, we assume this did not influence the outcome of this study since we expect random changes in haematocrit in the patients before and after implementation of the protocol.

Another limitation of the study is the retrospective design of the study. Ideally, a randomised study would have been performed. We assume, however, a random distribution of comorbidities and drug use. We adjusted for age and gender. Since information about the reason for admission, comorbidities, drug use and duration of admission was not available, we could not study the effect of these parameters as possible confounders. In addition, we could not study the effect of implementation of the intervention on the duration of admission and number of readmissions. Unfortunately, information about the time of glucose measurement was not available either. Therefore we could not examine the separate effect on fasting, pre- or postprandial glucose measurements.

In conclusion, after implementation of a new protocol to standardise inpatient care of diabetes mellitus by an internist and diabetes specialist nurse, we established a decreased risk of hyperglycaemia of 76% without an increased risk of developing hypoglycaemia. Implementation of this protocol required frequent glucose measurements which is possible due to point of care glucose measurements. However, the point of care measurement is only possible if the performance of the glucose device fulfils strict criteria on total error and other references. Before implementing adjustment of insulin dosage based on point-of-care measurements, the quality of glucose POCT devices should always be checked with the central hospital laboratory. In the future, we would like to study the influence on morbidity and mortality and the duration of admission and prevalence of readmissions.

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