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Real-world practice level data analysis confirms link between variability within Blood Glucose Monitoring Strip (BGMS) and glycosylated haemoglobin (HbA1c) in Type 1 Diabetes

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Summary

Aims/Hypothesis: Our aim was to quantify the impact of Blood Glucose Monitoring Strips variability (BGMSV) at GP practice level on the variability of reported glycated haemoglobin (HbA1cV) levels.

Methods: Overall GP Practice BGMSV and HbA1cV were calculated from the quantity of main types of BGMS being prescribed combined with the published accuracy, as % results within ±% bands from reference value for the selected strip type. The regression coefficient between the BGMSV and HbA1cV was calculated. To allow for the aggregation of estimated three tests/day over 13 weeks (ie, 300 samples) of actual Blood Glucose (BG) values up to the HbA1c, we multiplied HbA1cV coefficient by √300 to estimate an empirical value for impact of BGMSV on BGV.

Results: Four thousand five hundred and twenty-four practice years with 159 700 T1DM patient years where accuracy data were available for more than 80% of strips prescribed were included, with overall BGMSV 6.5% and HbA1c mean of 66.9 mmol/mol (8.3%) with variability of 13 mmol/mol equal to 19% of the mean. At a GP practice level, BGMSV and HbA1cV as % of mean HbA1c (in other words, the spread of HbA1c) were closely related with a regression coefficient of 0.176, $P < 0.001$. Thus, greater variability in the BGMS at a GP practice level resulted in a greater spread of HbA1C readings in T1DM patients. Applying this factor for BGMS to the national ISO accepted standard where 95% results must be ≤±15% from reference, revealed that for BG, 95% results would be ≤±45% from the reference value. Thus, the variation in BG is three times that of the BGMS. For a patient with BG target @10 mmol/L using the worst performing ISO standard strips, on 1/20 occasions (average 1/week) actual blood glucose value could be >±4.5 mmol/L from target, compared with the best performing BGMS with BG >±2.2 mmol/L from reference on 1/20 occasions.

Conclusion: Use of more variable/less accurate BGMS is associated both theoretically and in practice with a larger variability in measured BG and HbA1c, with implications for patient confidence in their day-to-day monitoring experience.

1 | INTRODUCTION

Accessible blood glucose monitoring (BGM) has been part of the management of diabetes mellitus, since 1981 with the launch of the ®Glucometer. The technology was initially applied to patients treated with insulin and more recently used by type 2 diabetes (T2DM) patients on oral hypoglycaemic agents, particularly the insulin secretagogues.

One measure of the accuracy of blood glucose monitoring systems is to establish the % of deviation of the measured value from the value measured by a reference analytical method that is needed to contain 95% of samples tested.

An "In Silico Study" by Breton and Kovatchev in 2010[1] applied BGM systems of increasing accuracy to establish the link to variations in actual levels of blood glucose. A derivative analysis of their results showed that the level of variation in blood glucose was 2.4 times higher than the level of accuracy in the BGM systems (Table 1).

They showed that improved accuracy would reduce risk of both short-term hypoglycaemic events and sustained periods of hyperglycaemia.

A patient's glycated haemoglobin (HbA1c) result captures an average blood glucose over previous 13 weeks and is now the cornerstone of diabetes management. However, this single result on its own cannot capture the shorter term glycaemic variation (GV) that is a result of less accurate BGM systems. Since type 1 diabetes patients measure and adjust their insulin dose up to 10 or more times/day, one element of the standard deviation in their HbA1c could be the standard deviation in blood glucose accuracy.

Previously, the standard for blood glucose monitoring systems was that 95% of results for samples with blood glucose >4.2 mmol/L (75 mg/dL) should be ± 20% from the reference value. But in 2013, an updated set of standards (ISO: 15197:2013)[2] was published specifying that for blood glucose >5.6 mmol/L (100 mg/dL) 95% of results should be ± 15%.

In the UK, the Greater Manchester Medicines Group[3] evaluated the provider strips data and reported their compliance (Table 2) with the new standard.

The interaction between BGM performance and patient experience of their self-diabetes management[4,5] illustrates how we may be able to improve further the metabolic control of the patients who use BGM strips.

The aim of this study was to see if the accuracy of the mix of strips used within each practice may be related to the spread of HbA1c control being achieved for type 1 diabetes patients (T1DM) within that practice and if so whether that level of correlation was similar to the level of correlation in blood glucose identified earlier "in silico".

TABLE 1 Relationship between BGM meter accuracy and expected Blood Glucose taken from Breton and Kovatchev (2010)

BGM Meter 95% results ±	@ 100 mg/dL blood glucose 95% results within ±
5%	12 mg/dl
10%	24 mg/dl
15%	39 mg/dl
20%	47 mg/dl

What's known about this subject?

- Accessible blood glucose monitoring (BGM) has been part of diabetes mellitus (DM) management since 1981.
- One measure of the accuracy of BGM systems is to establish the statistical values for each type of strip of % deviation of the measured value from the value measured by a reference analytical method.

What is the key question?

- To determine how accuracy of the mix of BGM strips used within each GP practice may relate to the spread of HbA1c for type 1 diabetes (T1DM) patients at GP practice level.

What are the new findings?

- The key finding is the linear relation between GP practice level lower prescribed strip accuracy (lower percentage of readings within 10% of the reference laboratory blood glucose) and increased variability in HbA1C for T1DM individuals.
- For a patient with BG target @10 mmol/l using standard BGM strips, on 1/20 occasions (average 1/week), their actual blood glucose value could be >±4.5 mmol/l from target, compared with the best performing BGMS with BG >±2.2 mmol/l from reference on 1/20 occasions.

How might this impact clinical practice in the foreseeable future?

- In the short term, use of less accurate BGM strips will contribute to unstable glycaemia for T1DM individuals and in the longer term could increase the development of diabetes complications. We suggest there are clear advantages to utilising best in class accuracy BGMS.

2 | METHODOLOGY

The National Health Service (NHS) publishes at GP practice level in the National Diabetes Audit (NDA)[6] the spread of HbA1C (% patients ≤48 mmol/mol (6.5%), % patients ≤58 mmol/mol (7.5%) and % patients ≤86 mmol/mol (10%)) and in GP prescribing data the number of each types of BGM strips being prescribed. Accuracy data for the various prescribed BGM strips are published in the scientific literature as % results >20%, >15%, >10%, >5% from the reference value.

The original complete patient level HbA1c and BGM strip level accuracy datasets were not available to us. Published results for

TABLE 2 Blood Glucose Monitoring Strips (BGMS) where accuracy data were available and used

Strip	GMMG ISO classification	3-year quantity	Trials	Samples	>25%	20%-25%	20%-15%	15%-10%	10%-5%	<5%	Variability
Aviva	Yes	380 170 055	19	2100	0.0%	0.0%	0.6%	5.3%	27.0%	67.0%	5.4%
Mobile	Yes	151 500 204	10	1200	0.0%	0.0%	0.1%	5.2%	28.0%	66.8%	5.3%
FreeStyle Optium	Yes	149 029 926	1	100	0.0%	0.0%	1.0%	9.0%	30.0%	60.0%	6.1%
GlucoRx Nexus	Yes	146 689 898	4	400	0.7%	4.0%	4.5%	12.8%	33.0%	45.0%	9.0%
FreeStyle Lite	Yes	126 726 538	8	800	0.0%	0.0%	3.4%	14.8%	31.1%	50.8%	7.4%
Contour Next	Yes	116 019 267	8	800	0.0%	0.0%	0.0%	1.8%	24.5%	73.8%	4.6%
WaveSense JAZZ	No Info	56 017 572	1	180	0.0%	1.1%	5.0%	16.1%	32.8%	45.0%	8.2%
OneTouch Verio	Yes	35 583 668	12	1300	0.0%	1.7%	4.8%	17.4%	31.5%	44.7%	8.4%
TRUEresult	Not Promoted	32 078 870	2	200	0.0%	0.0%	0.0%	8.0%	28.0%	64.0%	5.7%
BGStar	Yes	26 179,688	2	360	0.0%	3.1%	3.9%	12.5%	31.4%	49.2%	8.2%
TRUEyou	Yes	21 534 310	2	200	0.0%	0.0%	1.5%	12.5%	31.0%	55.0%	6.7%
Mylife Pura	Yes	21 337 759	3	300	0.0%	4.3%	14.3%	21.7%	25.0%	34.7%	10.8%
OneTouch Vita	Not Promoted	19 423 110	1	100	0.0%	0.0%	10.0%	22.0%	33.0%	35.0%	9.3%
Active	Yes	19 314 119	5	600	0.0%	0.0%	0.0%	0.2%	22.0%	77.8%	4.2%
Omnitest 3	No Info	17 204 404	1	180	0.0%	5.0%	3.9%	12.2%	31.1%	47.8%	8.8%
Microdot+	Excluded	12 254 656	1	200	0.0%	1.0%	5.0%	13.0%	38.0%	43.0%	8.0%
Element	Yes	8 936 507	1	100	8.0%	9.0%	8.0%	21.0%	29.0%	25.0%	13.5%
OneTouch Select Plus	Yes	1 385 801	1	100	0.0%	0.0%	3.0%	13.0%	32.0%	52.0%	7.1%
GlucoRx Original	Not Promoted	1 272 250	2	300	0.0%	17.0%	17.3%	27.0%	23.3%	15.3%	14.0%
Performa	Yes	1 000 300	13	1500	0.0%	0.1%	0.3%	6.3%	27.5%	65.7%	5.6%

both HbA1c and BGMS are shown as % of results falling within given bands. We calculated a "variability" measure within each practice in each year using methodology principles similar to standard deviation.

We conducted the analysis in the following way:

1. Considered the available GP practice level National Diabetes Audit for type 1 data over a period of 3 years (2013_14, 2014_15, 2015_16) in England.
2. Calculated from % HbA1c results in each band (≤48 mmol/mol (6.5%), 48-58 mmol/mol (6.5%-7.5%), 58-86 mmol/mol (7.5%-10%)and >86 mmol/mol (>10%)) an estimated mean and "variability" of HbA1c in each practice.
3. Consolidated the values taken from the various published scientific reports to generate an overall average published % of strips falling in each band (<5%, 5%-10%, 10%-15%, 15-20% and >20%), for the 40 main types of blood glucose strips. To reduce the measurement methodology variation, the sources of BGMS accuracy data were restricted to three papers with similar methodology covering 20 strip types, 73% of the strips being prescribed and only taking results for strips tested since 2011.[7-9]
4. This was then weighted by the total number of strips of each type prescribed in each practice in that year to calculate the average percentage in each accuracy band in that practice and from this the annual "variability" of BGMS accuracy for that practice was calculated.
5. Calculated the level of correlation between the practice BGMS and HbA1c variability.
6. Assumed that since HbA1c is a measure of the average blood glucose over 3 months, and during that period there would be around three interventions/day to adjust blood sugar, each HbA1c reflects an average of over 300 samples. With a normal distribution, the standard deviation of HbA1c can be multiplied by the square root of number of samples 17.3 to establish the standard deviation in the actual blood glucose.

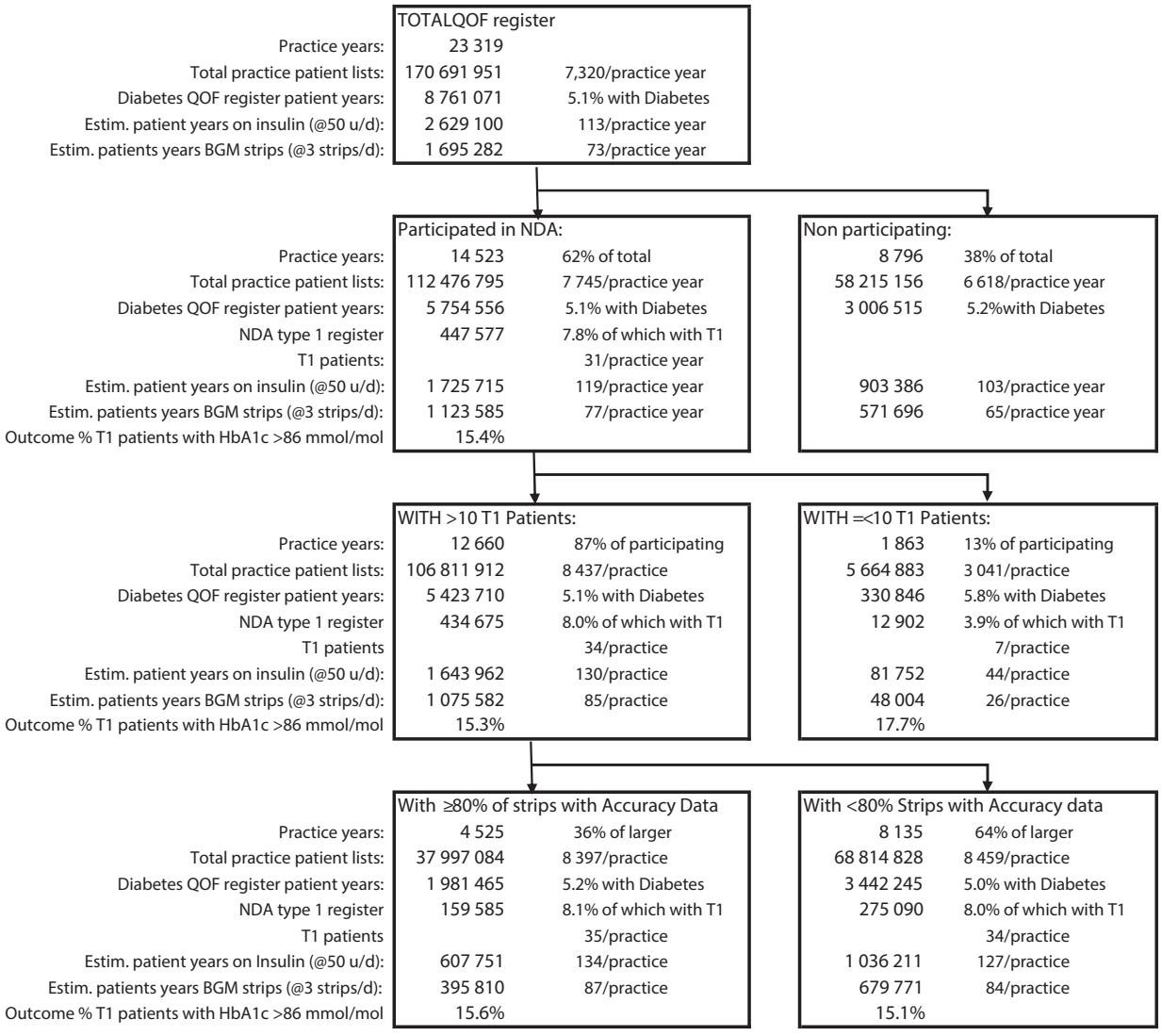

FIGURE 1 Flow chart describing GP practice selection

7. Compared this empirical measured correlation factor to the Breton[1] in silico-based calculated factor.
8. Considered what this factor might mean to patients when using either ISO Standard or best in class strips.

The restrictions & assumptions were as follows:

- Accuracy varies by strip and meter and changes over time and there is no central register of strip accuracies
- We were looking at T1DM. However, both insulin and BGMS are used for some T2DM patients and types of strips may be differently prescribed between the two main forms of diabetes
- There are also many other factors that would impact HbA1c spread and outcome
- We have assumed that distributions are broadly normal, so that two standard deviations would cover just over 95% of blood glucose results.

2.1 | Statistics

Data were aggregated from the various downloaded CSV data files using Excel 2016 64bit Power Pivot and aggregated data were statistically analysed using Analyse-it add-in.

3 | RESULTS

3.1 | Selection of practices

Figure 1 shows the selection of practice years included into the study. There are around 7500 GP practices in England that provide data for the Quality & Outcomes framework (QOF) each year. So, in the 3 years selected, there is a total of 23 319 practice years of data providing data for 170.7 million total patient years in which there are 8.7 million patient years of diabetes. Results for Type 1 diabetes are required and those are provided in the NDA in which 14 523 practice years (62% of total) participated and 66% of diabetes patients and total of 447 000 patient years of type 1 were included with an average of 31 type 1/practice. To avoid small number effects, 1853 practices with ≤10 type 1 patients were excluded. Four thousand five hundred and twenty-four practice years were then included where use of BGM strips with accuracy data was >80% of total strips significant enough to generate sufficient impact. These practices were not significantly different in size or level of diabetes to the other practices excluded.

Out of the total of 70 different types of strips prescribed, only 20 types were evaluated in accuracy studies selected. These covered 73% of the total strips prescribed. Figure 2 shows the % of total strips used in the period by type and highlights those contained within the accuracy study. The main strips used over this period were Aviva, GlucoRx Nexium, Mobile, Contour Next, FreeStyle

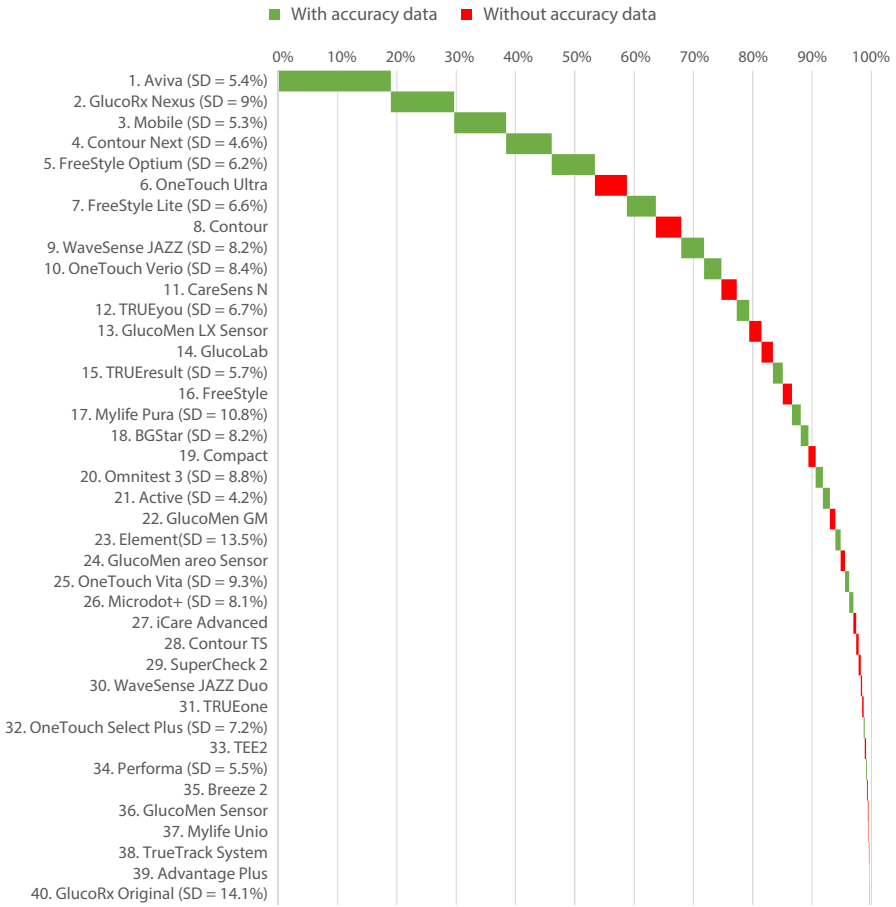

FIGURE 2 Overall cumulative mix of strip used over 3 years as a percentage of total use

Optium and OneTouch Ultra which together accounted for 58% of BGM strip used in these years.

3.2 | Accuracy and variability at practice level (Figure 3)

Practices prescribe mixes of strips. By aggregating the number of strips of each type with % that fall in each band for that strip type, the average % of strips falling within each band was calculated in each practice.

The accuracy variability was calculated as square root of the sum of the percentage of strips in each band times the square of the distance of the band from the reference zero. Figure 3 shows the distribution of strip accuracy within bands, comparing the average of practices in the median decile with those the top and bottom deciles when ranked by accuracy variability. The average variability of BGMS in the highest variability decile was 8.2% compared with 5.2% in the lowest decile. In practices with highest accuracy/lowest variability (Brown) over 66% of BGMS, blood glucose results could be expected to be within 5% of the reference value while those with the lowest accuracy/highest variability (Green) this would be below 50%. At the other end in practices with highest accuracy/lowest variability (Brown) less than 3% of strips, results could be expecting to be more than 15% of the reference value while those with the lowest accuracy/highest variability (Green) this would be above 10%.

3.3 | Glycaemic control variability at practice level (Figure 4)

The NDA HbA1c published values have been reworked to show % of patients' results in each practice in each of four bands (<46, 46-58, 58-86, >86). From this, an estimated mean and variability (square root of the sum of the % in each band times square of the difference from that mean) were calculated for each practice. The practices were then ranked by variability. The median decile with 15% of results >86 mmol/mol (10%) had a calculated mean HbA1c of 68.6 mmol/mol (8.3%) and a calculated variability (HbA1cV) around that mean of 12.9 mmol/mol which is 19% of mean. The average variability for practices in the decile with highest HbA1c variability was 23% of the mean value, while those with lowest variability had a calculated variability (HbA1cV) of 14% of mean value. GP Practices in the highest variability decile (Green) have patients with wider spread of HbA1c results than those in the lowest spread decile (Brown).

3.4 | Regression modelling for the relation between strip accuracy and HbA1C (Figure 5)

The relation between the practice values for BGMS variability and HbA1c was determined. Outcome variability as % of the mean HBA1c was calculated. The regression line between BGMS variability and %HbA1c variability with the points plotted showing the actual average of the deciles of GP practices sorted by BGMS variability. The slope of the regression line is 0.176. Thus, the spread of HbA1C values for T1DM patients at the GP practice was greater for the practices using less precise BGMS.

Applying the figure 17.3 (to convert HbA1c variability into blood glucose variability, modelled on three tests/day over 13 weeks (300 samples), the increase in blood glucose variability would be three times higher than the corresponding BGMS variety.

Applying the above findings to the BGMS strips currently being used (Table 3), we would see those conforming to the current ISO standard which require 95% of results to be within 15% delivering for an expected meter reading of 10 mmol/L one result in 20 ie, 1/week the actual blood glucose levels more than 2.7 mmol/L. If this was applied to current best in class strips where 95% of results are within 7.5%, then the outcome in blood glucose control would be significantly improved with in comparison, 1/week the actual blood glucose levels being more than 1.4 mmol/L.

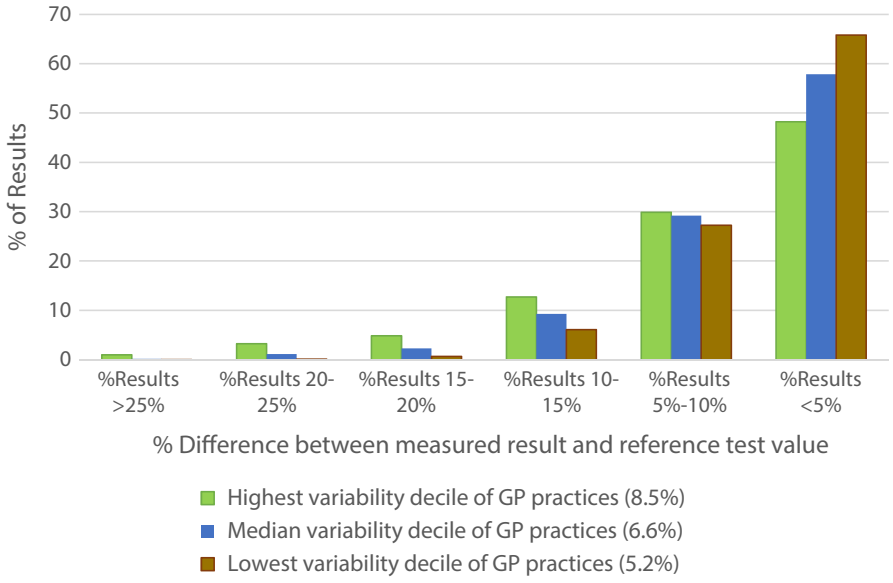

FIGURE 3 BGMS variability vs % of BG results within specified bands in relation to the reference BG value for ranked by their BGM strip variability (lowest, median and highest decile)

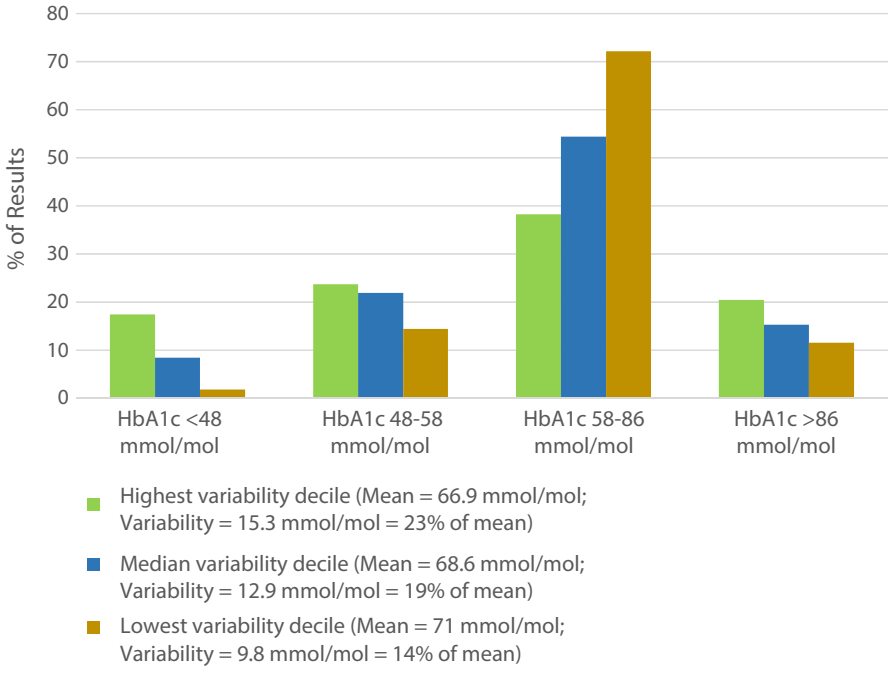

FIGURE 4 HbA1c variability: distribution of HbA1c results within GP practices in highest, median and lowest deciles of HbA1c variability for each HbA1c band

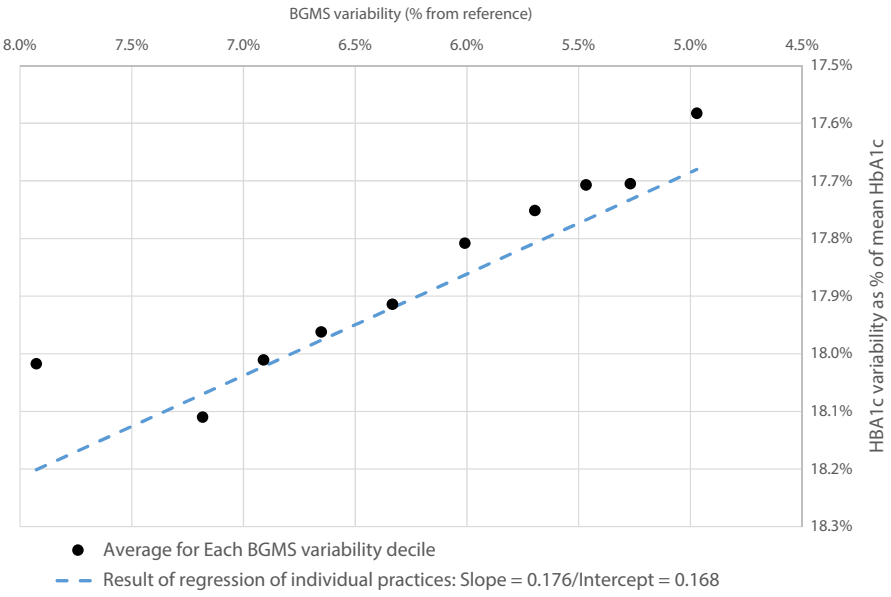

FIGURE 5 Relation at GP practice level between BGMS variability and HbA1c variability taken as % of the mean HbA1c for that practice. The points reflect the average within the deciles of practices sorted by BGMS variability.

4 | DISCUSSION

People with T1DM have much greater variation in blood glucose with levels both higher and lower readings than would be expected in a person without the condition. These variations derive from the mix of day-to-day living and the interventions that people are utilising. The aim of all therapeutic interventions should be to control both the overall average blood glucose and the range of variation of blood glucose.

We have identified one potential source of variation as the accuracy of the testing strips that patients use multiple times each day to adjust titration of their therapy. The variation in BG is three times that of the BGMS.

The key finding of our analysis is the linear relation between GP practice level prescribed strip accuracy (greater percentage of readings within 10% of the reference laboratory blood glucose) and less variability in HbA1C for T1DM individuals. This has significant implications for achieved HbA1c and therefore the longer term health prospects of people with T1DM.[10,11]

With the caveat that BGM strip use includes all prescriptions at a GP practice level—that is the BGM strip use at a GP practice level is quantified for all diabetes patients, not just the T1DM patients—these real-world findings at a GP practice level accord with the in silico findings previously reported by Breton and Kovatchev.[1]

Based on these findings, we determined that the difference in the spread of BGMS variability across GP practices depending on their

TABLE 3 Applying findings to ISO standard and best in class BGMS

	ISO standard accuracy	Best in class accuracy
95% results are within % of reference value	15%	7.5%
Equivalent meter variability	7.50%	3.75%
Consequent blood glucose variability	14%	7%
95% Blood glucose within % of reference value	27%	14%
With blood glucose @10 mmol/L difference is	2.7 mmol/L	1.4 mmol/L

profile of strip type use, between the top and bottom decile of 2.9% is associated with an increase in HbA1c variability of 0.42% for the GP practices. This would correspond when adjusted for sample frequency to a variability of blood glucose of 7%. This compares very closely to the predicted Blood Glucose variability of 6% for a 2.5% change in meter standard deviation taken from the Breton model.[1]

The clinical corollary of our analysis is that for an individual with T1DM with blood glucose at 10 mmol/L using ISO standard BGMS, on 1/20 occasions (average 1/week) the actual blood glucose value could be >±4.5 mmol/l from target, compared with the best performing BGMS with BG >±2.2 mmol/l from reference on 1/20 occasions.

Poor blood glucose monitoring strip accuracy has been shown to induce loss of patient confidence in hour-to-hour and day-to-day blood glucose monitoring[4,5] and increase the potential increased risk of hypoglycaemia[12] to which is now added the cumulative damage of running a higher HbA1C over time.[10] Reduction in the proportion of high outlying patients in terms of HbA1C would have significant benefit to people with diabetes in terms of reduced short-term hypoglycaemia[13] and long-term complication rates.

Investing in improved accuracy of BGMS, can be offset against the benefits of less variability in HbA1C values in the longer term and we would speculate, potentially less patients suffering untoward hypoglycaemia because of measurement inaccuracy.

In 2015-2016, in the English NHS spent £170 million on BGM strips.[14] Thus, a very large amount of investment goes into the monitoring of blood glucose. Clearly, it is important that the benefits of such a large investment are maximised. A recent very important development for glycaemic monitoring in T1DM has been the introduction of the continuous glucose monitor (CGM) FreeStyle Libre Flash blood glucose monitoring device.[15] This has been very well received by patients. It was recently demonstrated with in silico modelling that BGM accuracy, and more specifically systematic positive or negative bias, has a significant effect on clinical performance (HbA1c and severe hypoglycaemia events.[16]

The limitations of this study include the fact that we do not have all the specifications of the BGM devices nor are all practices in England included. Nevertheless, the 4650 GP practices included are very similar in terms of T1DM patients' profile from the remainder of GP practices. A strength of the study is that it utilises national scale data.

5 | CONCLUSION

We have determined that at GP practice level prescribing BGM strips with lower accuracy is associated with a greater spread of HbA1C in the people with T1DM attending that practice. In the short term, this will contribute to unstable glycaemia including more hypoglycaemia for T1DM individuals and in the longer term may increase the development of diabetes complications. Our results suggest there are clear advantages to utilising best in class accuracy BGMS. The health economic cost of this will be the subject of a subsequent paper.

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No external funding was obtained for this work.

DISCLOSURE

No author has any conflict of interest to declare in relation to the findings presented here.

AUTHOR CONTRIBUTIONS

Adrian Heald is the first author and Mike Stedman the principal investigator for the work done to bring this paper to fruition. Mark Livingston provided invaluable scientific advice and helped with manuscript preparation. Anthony Fryer reviewed all sections of the paper in relation to scientific relevance and provided support to the research group. Dr Gabriela Moreno contributed to the writing of the manuscript and literature review. Ian Laing advised on all parts of the paper. Some statistical analysis was by Simon Anderson and Mark Lunt gave statistical advice and reviewed the analysis results. Robert Young and Roger Gadsby provided review of all sections of the manuscript and gave invaluable assistance in writing the discussion section.

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REFERENCES

1. Breton MD, Kovatchev BP. Impact of blood glucose self-monitoring errors on glucose variability, risk for hypoglycemia, and average glucose control in type 1 diabetes: an in silico study. *J Diabetes Sci Technol*. 2010;4(3):562-570.
2. International Organization for Standardization 15197. *In vitro diagnostic test systems – Requirements for blood-glucose monitoring systems for self-testing in managing diabetes mellitus*. In: systems ITCItaivdt, editor. Geneva, Switzerland: International Organization for Standardization; 2013.

3. Greater Manchester Medicines Management Group. *Blood glucose test strips (BGTS) evaluation protocol and results*. In: Team MO, editor. Salford, UK. https://www.gmmmg.nhs.uk/docs/guidance/160421-BGTS-Evaluation-Report-Update-April-2016-v4-2.pdf. Accessed November 10, 2017.
4. Bolinder J, Antuna R, Geelhoed-Duijvestijn P, Kroger J, Weitgasser R. Novel glucose-sensing technology and hypoglycaemia in type 1 diabetes: a multicentre, non-masked, randomised controlled trial. *Lancet*. 2016;388(10057):2254-2263.
5. Pearson SM, Ajjan RA. Flash Glucose Monitoring in Younger Individuals with Diabetes: accuracy and Patient Experience in Real-World Settings. *Diabetes Technol Ther*. 2018;20(1):4-5.
6. National Diabetes Audit. *National Diabetes Audit 2013-2014 and 2014-2015*. In: Health and Social Care Information Centre, editor. United Kingdom: Diabetes UK, 2016.
7. Freckmann G, Schmid C, Baumstark A, Pleus S, Link M, Haug C. System accuracy evaluation of 43 blood glucose monitoring systems for self-monitoring of blood glucose according to DIN EN ISO 15197. *J Diabetes Sci Technol*. 2012;6(5):1060-1075.
8. Freckmann G, Baumstark A, Schmid C, Pleus S, Link M, Haug C. Evaluation of 12 blood glucose monitoring systems for self-testing: system accuracy and measurement reproducibility. *Diabetes Technol Ther*. 2014;16(2):113-122.
9. Peter Müller AH, Stephan Peter. Assessing system accuracy of blood glucose monitoring systems using rectangle target plots. *J Diabetes Sci Technol*. 2016;10(2):350-365.
10. Diabetes C, Complications Trial Research G, Nathan DM, et al. The effect of intensive treatment of diabetes on the development and progression of long-term complications in insulin-dependent diabetes mellitus. *N Engl J Med* 1993;329(14):977-986.
11. Diabetes Control and Complications Trial (DCCT)/Epidemiology of Diabetes Interventions and Complications (EDIC) Study Research Group. Intensive diabetes treatment and cardiovascular outcomes in type 1 diabetes: the DCCT/EDIC study 30-year follow-up. *Diabetes Care*. 2016;39(5):686-693.
12. Leese GP, Wang J, Broomhall J, et al. ; DARTS/MEMO Collaboration. Frequency of severe hypoglycemia requiring emergency treatment in type 1 and type 2 diabetes: a population-based study of health service resource use. *Diabetes Care*. 2003;26(4):1176-1180.
13. Frier BM. Hypoglycaemia in diabetes mellitus: epidemiology and clinical implications. *Nat Rev Endocrinol*. 2014;10(12):711-722.
14. Heald AH, Livingston M, Fryer A, et al. Route to improving Type 1 diabetes mellitus glycaemic outcomes: real-world evidence taken from the National Diabetes Audit. *Diabet Med*. 2018;35(1):63-71.
15. Campos-Náñez E, Breton MD. Effect of BGM accuracy on the clinical performance of CGM: an in-silico study. *J Diabetes Sci Technol*. 2017;11(6):1196-1206.
16. Fokkert MJ, van Dijk PR, Edens MA, et al. Performance of the FreeStyle Libre Flash glucose monitoring system in patients with type 1 and 2 diabetes mellitus. *BMJ Open Diabetes Res Care*. 2017;5(1):e000320. https://doi.org/10.1136/bmjdrc-2016-000320.

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