Diagnostic accuracy of point of care tests measuring glycosylated haemoglobin (HbA1c) for glycemic control: A field study in India

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Abstract:

Objectives: This study was performed to estimate diagnostic accuracy of the two commercially available point-of-care tests to identify poor glycemic control defined by HbA1c levels, with HPLC as a reference.

Settings: The study was carried at two locations, general medical out-patient department of a teaching medical college in Bhopal (urban), and a primary health care centre in rural area in the state of Madhya Pradesh, India.

***Participants*:** All individuals with diabetes mellitus who presented to the health care facility for assessment of glycemic control. We excluded participants who denied a written informed consent. No other exclusions were used. We compared HbA1c estimated from two index tests (Hemocue Hb501, Sweden; SD Biosensor, South Korea) from capillary blood samples with HPLC performed from venous blood, as a reference standard.

Primary and secondary outcome measures: Diagnostic properties of index tests such as sensitivity, specificity, positive and negative predictive value and diagnostic accuracy for identifying poor glycemic control were primary outcome measures. Lin's concordance correlation coefficient (CCC) was secondary outcome measure.

Results: Out of 114 patients, all received reference standard, 103-Hemocue A1C test, and 110- SD Biosensor test. Overall both the index-tests had similar diagnostic accuracy estimates. The area under the Receiver Operating Curve for SDA1c device was 0.935 (95%CI 0.886-0.983), and for Hemocue device was 0.938 (95%CI 0.893-0.984). The Hemocue device HbA1c value of above 7.0 (positive) correctly predicted poor glycemic control 92% times (81.58% for SD device). There were 4 vs. 11 device failures and 14 vs. 12 failures with SD and Hemocue respectively. Ambient air temperatures were no different for the device test failures.

Conclusions: Commercially available point-of-care tests evaluated in this study are comparable and an acceptable alternative to HPLC based measurements for assessment of glycemic control. Tests and device failure rates of both the index tests are similar.

Key words: HbA1c, diagnostic accuracy, point of care, diabetes, glycaemic control

Strengths and limitations of this study

- Current study from tropical middle-income country, conducted in actual operational conditions demonstrates good concordance of HbA1c values by two different Point-of-Care kits.
- The study was conducted in two different facilities, where the ambient temperature ranged from 25-42 degrees and range of HbA1c tested was also wide ranging from 4.5 to 15.3%.
- Results of the study provides evidence for adoption of Point-of-Care HbA1c testing for assessment of glycemic status in patients with diabetes.
- Our sample size was modest, yet this is one of the large Point-of-Care HbA1c studies conducted.
- Our testing environment was at variance with what would have been prescribed by the manufacturers, but this limitation is inherent, as actual temperature and humidity levels in developing country facilities are likely to be less than ideal.

Introduction

The number of people living with diabetes in India is estimated to be about 60 million, a number which is expected to increase to 130 million by the year 2030. (1) Achieving optimal glycaemic control is central to management of Diabetes Mellitus. Glycosylated Hemoglobin level (HbA1c) is a well-established measure of glycemic control, central to the care of people living with diabetes mellitus. With rising prevalence of diabetes, it is necessary to make HbA1c test available as a point of care test at all levels of care.

The circulating glucose attaches with the hemoglobin fraction of red blood cells and form glycosylated hemoglobin. Long term glycemic control up to 3 months (representing the life span of red blood cells) is best determined by HbA1c levels. The use of HbA1c in the management of diabetes has been well established since the DCCT and UKPDS trials.(2–4) American Diabetic Association (ADA) in 2009 updated their guideline of diagnosis of diabetes, taking HbA1c into account.(5) Since then HbA1c has been used as a convenient marker for both diagnosis and follow up of diabetes patients using the cutoffs of 6.5% and 7% respectively.(6) HbA1c based targets are more meaningful as they provide an assessment of glycemic control over the previous 2-3 months,

unlike blood glucose measurements obtained at a single point of time that are influenced by diet, exercise, and drug adherence in the previous few hours. (7) The HbA1c value is the gold standard measurement of micro vascular complications of diabetes and has become the cornerstone in diabetes care.(7)

Various methods available for measurement of HbA1c level, separate HbA1c from other types of hemoglobin using charge difference (e.g. ion-exchange high performance liquid chromatography [HPLC], electrophoresis or isoelectric focusing), structural difference (e.g. affinity chromatography or immunoassay) or chemical analysis (e.g. photometry and spectrophotometry).(8–10,10–13) More than 30 different methods have been described to estimate HbA1c.(14) Due to the inconsistency in the technique used and reporting format, ADA recommends IFCC units (mml/mol) and derived NGSP units (%) using the IFCC-NGSP master equation.(7,16) The methods certified by National Glyco-hemoglobin Standardization Program (NGSP) a US-based organization relates individual techniques to HbA1c values as obtained in the landmark DCCT trial. The most commonly used techniques are ion-exchange high performance liquid chromatography (HPLC), capillary chromatography, borate affinity assay, and immunoassay; HPLC being considered as the gold standard.(16) However it has greater technical needs, including equipment, expenditure, and longer turnaround times. In past few years the concept of point of care (POC) HbA1c testing has emerged. Commonly used POC, HbA1c assays use the principles of borate affinity or immunoassay. In borate affinity assays glycated-haemoglobin binds to borate resins, with a potential to overestimate HbA1c, as the technique is not HbA1c specific. In contrast immunoassay uses Anti-HbA1c antibodies against glycated N-terminal of beta-haemoglobin chain. While this technique is attractive, interference with other hemoglobin chains remains a concern. (15)

Previous HbA1c diagnostic accuracy studies were conducted in high-income countries that have more controlled environmental and logistic conditions for storage of test kits and operation of the equipment. Ours is the first study from a tropic middle-income country, conducted in actual operational environment. The current study was designed to answer two research questions: a) Among individuals with diabetes mellitus do point of care HbA1c measurement devices (based on immunoassay or borate affinity principle), as compared to HPLC as a reference standard, are accurate to make an assessment of optimal glycemic control (HbA1c $\leq$ 7%); b) In a community based setting in a rural area, is use of POC device to estimate HbA1c level feasible. We aimed to compare two commercially available point-of-care devices to compare their performance with respect to accuracy and feasibility.

Methods

Design: A cross-sectional diagnostic accuracy and feasibility study

Setting: The study was carried at two locations, medical out-patient department at All India Institute of Medical Sciences Bhopal, Madhya Pradesh (Urban), and Centre for Rural Health AIIMS (CRHA) located at Primary Health Centre at Chiklod, Madhya Pradesh (Rural). Individuals with diabetes mellitus who seek care at both these facilities were evaluated for glycemic control.

Participants: The study sought to include all individuals with diabetes mellitus who presented to the health care facility for assessment of glycemic control. It was necessary for the individuals to have been previously diagnosed with Diabetes (based on ADA criteria: fasting plasma glucose of 126mg/dL or above or post-meal plasma glucose of 200mg/dL or above or HbA1c level of 6.5% or above) at least three months prior to date of inclusion in the study. We obtained a written informed consent from all eligible participants. We excluded participants who denied a written informed consent. No other exclusions were used. Due to logistic reasons, the participants were sampled from these facilities once every week for the study duration.

Patient and public involvement: This study was implemented at out-patient settings of a teaching hospital and rural primary health centre. Study participants were not involved in design of the protocol. Participants were enrolled after obtaining written informed consent. Results of biochemical investigations were communicated to participants and were appropriately managed or referred. Patients were not directly involved in dissemination of results of this research.

Study procedures: All eligible and consenting participants were administered a questionnaire to collect information about demographics, duration of diagnosis of diabetes mellitus, their current therapies, and any past history of a hemoglobinopathy. Subsequently the following samples for index test and the reference standard were collected within a 10 minute interval of each other. We first collected a 2mL venous sample in an EDTA tube, that was immediately stored between 4 and 8 degree Celsius in an ice-pack-containing vaccine carrier. These samples were transported to the laboratory in the same day in a temperature-controlled environment for HPLC based HbA1c estimation (Reference Standard). The test was performed in a NABL accredited laboratory. Then we collected capillary blood samples by finger-prick. We collected one drop of capillary blood (about 5µL) for each of the index tests: a Borate affinity based point-of-care test (Hemocue A1c 501, Sweden) and an immunoassay based point-of-care test (SD A1c care Bioassay, South Korea). The characteristics of the two index tests are detailed in Table 1. The point-of-care tests were performed in front of the patient, by using standard techniques as per manufacture's guidelines. Briefly, in the borate affinity meter (Hemocue A1c 510) blood sample collected by a reagent pack

(which draws appropriate volume into the reagent pack), and the reagent pack is inserted in the cartridge. Cartridge is then inserted into the machine, and the results are displayed on the meter in three minutes. In the immunoassay meter (SD A1c care) a drop of blood (about 5µL) is collected in a reagent tube, and allowed to mix for a minute. A test strip is inserted into the meter, and 5µL of blood-reagent mixture is applied to the sample port on the strip. The strip is inserted into the meter and results are obtained in three minutes. Both the index tests were conducted, and interpreted, blinded to the results of the reference standard. The HPLC results were available only the next day.

For all the tests we will collect the following four variables to know the feasibility of the point-of-care HbA1c assays: i) Device failure events – the device does not get powered on, or is unable to perform a measurement. ii) Test failure events – the device gives an error message or the testing cartridge is prematurely ejected and no meaningful output is received. Test failure events are expected to result in wastage of the testing strips or cartridges. We also measured ambient room-temperature of the facility where the tests were carried out, using a temperature logger device (Lascar Electronics).

Table 1: Characteristics of the two index tests

Characteristics	HemoCue® HbA1c 501 System	SD Biosensor A1c Care
Principle	Boronate affinity assay for determination of HbA1c percentage in whole blood	Immuno assay
Calibration	Factory calibrated and traceable to IFCC and NGSP/DCCT	Easy Calibration by cartridges
Sample Material	Capillary or venous whole blood	Capillary or venous whole blood
Measurement Range	20 – 130 mmol/mol (IFCC) 4.0 – 14.0 % (NGSP)	20 - 140 mmol/mol (IFCC) 4.0 - 15.0 % (NGSP)
Coefficient of Variation	CV < 3%	CV < 3%
Output Results	In 5 minutes	In 3 minutes
Sample Volume	4 µL	5 µl
Dimensions	198 mm (H) × 217 mm (W) × 136 mm (D)	163 mm (H) x 96 mm (W) x 56 mm (D)
Weight	1.600 kg	0.450 kg
Storage Temperature	Analyzer: 10 – 35 °C (50 – 95 °F) Test Cartridge: unopened 2-32 °C (36-90 °F)	0 °C– 32 °C
Operating Temperature	17 – 32 °C (63 – 90 °F)	15 to 32 °C (59 to 90 °F)
Power	9 V DC / 1.5 A	12 V DC/ 1.5 A
Battery Backup	Absent	4 AA Battery is used to run analyzer
Interface	Printer, PC and Barcode Scanner	Thermal Printer, Barcode Scanner, HbA1c Management Software
Quality Control	Built-in self test Check Cartridge, system can be verified using liquid controls	Built-in self test Check Cartridge
Cost of Analyzer	INR 200,000 (About 3500 USD)	INR 50,000/- (About 850 USD)
Cost per test	INR 300/- (About 5 USD)	INR 200/- (About 3.5 USD)

Statistical analysis

We have summarized nominal variables with frequency and percent and numerical variables with mean and standard deviation. Concordance in estimated HbA1c values was visualized by creating Bland-Altmann plots and scatter plots. For quantifying concordance, we have estimated Lin's concordance correlation coefficient, Pearson's correlation coefficient and Area Under ROC Curve

(AUC). Lin's Concordance Correlation Coefficient (CCC) is used to examine agreement between two continuous measurements. Like Pearson's correlation coefficient, CCC ranges from -1 to +1. However, if one method of measurement differs systematically from other method then we will get higher value of correlation coefficient but concordance is not ensured. Therefore, Lin's CCC is better measurement when our aim is to assess agreement or concordance. For qualitative agreement, using a cut-off of 7% we estimated traditional measures of diagnostic accuracy (Sensitivity, Specificity, Positive and Negative predictive values and Likelihood ratios). We measured precision of our estimates by calculating 95% confidence intervals. Data analysis was done using SPSS software (IBM SPSS Statistics for Macintosh, Version 26.0. Armonk, NY: IBM Corp.) and R software.

Results

The study was conducted between April and September 2016. A total of 114 patients were included in the study. Most patients were middle aged (Mean age 53.4 years (SD 11.5)), with an age range of 18 to 80 years. A total of 45 (39.5%) participants were women. The characteristics of the study population are detailed in Table 2.

A valid reference standard HbA1c by HPLC method was obtained in all 114 participants. The mean HbA1c level by reference standard was 8.03% (SD 2.02). A valid HbA1c estimate by index Hemocue A1c501 and SDA1c Biosensor was obtained in 103 and 110 participants respectively. As compared to HPLC, the median HbA1c values were similar in SDA1c device, and Hemocue A1c device. The distribution of the HbA1c values is depicted in Figure 1. Lin's concordance correlation coefficient (CCC) for both SDA1c device (0.88 95% CI 0.84 - 0.92) and Hemocue device (0.85 95%CI 0.80 - 0.90) indicated good concordance. The Bland-Altmann plots (Plot of difference between index test and reference standard vs. the Mean HbA1c value by both techniques) show majority of the mean values between the acceptable range of +/- 2SD. There is no difference in the distribution of values for lower (<7%), intermediate (7-10%) and high (>10%) HbA1c. (Figure 2)

Table 2: Study population (n=114)

Variable	n	%
Female Gender	45	39.5
Complications / Comorbidities		
Retinopathy	8	7.0
Nephropathy	13	11.4
Neuropathy	23	20.2
Coronary Artery Disease	12	10.5
Cerebrovascular Disease	1	0.9
Peripheral Vascular Disease	4	3.5
Diabetic foot ulcers	2	1.8
Hypertension	23	20.2
Dyslipidemia	17	14.9
Therapies		
Metformin	69	61.1
Sulphonylurea	38	33.6
Thiazolidione	2	1.8
Alpha glucosidase inhibitor	3	2.7
DPP4inhibitors	11	9.8
Insulin	16	14.4

SD A1c assay for detection of poor glycemic control (HbA1c value >7%) was 95.38% sensitive (95%CI 87.29, 98.42), but only 68.89% specific (95%CI 54.33-80.47). In contrast the sensitivity of Hemocue device was 90.63% (95%CI 81.02-95.63) and specificity was 87.18% (95%CI 73.29-94.2). A Hemocue device HbA1c value of above 7.0 (positive test) correctly predicted poor glycemic control 92% times (vs. 81.58% for SD device). SD device HbA1c value of less than 7.0 (negative test) correctly predicted optimal glycemic control 91% times (vs. 85% by Hemocue device). (Table 3) The overall test performance by receiver operating curve (ROC) derived analysis area under the curve (AUC) analysis was similar. The AUC for SDA1c device was 0.935 (95%CI 0.886-0.983), and for Hemocue device was 0.938 (95%CI 0.893-0.984). (Figure 3)

Table 3: Diagnostic accuracy of point of care HbA1C measurement

Comparison	SD vs HPLC (n=110)	Hemocue vs HPLC (n=103)
True Positives	62	58
False Positives	14	5
False Negatives	3	6
True Negatives	31	34
Diagnostic Accuracy	84.55 (76.64, 90.12)	89.32 (81.88, 93.93)
Sensitivity	95.38 (87.29,98.42)	90.63 (81.02,95.63)
Specificity	68.89 (54.33,80.47)	87.18 (73.29, 94.4)
PPV	81.58 (71.42,88.7)	92.06 (82.73, 96.56)
NPV	91.18 (77.04,96.95)	85 (70.93-92.94)
LR+	3.066 (2.6 -3.5)	7.069 (4.76-10.5)
LR-	0.067 (0.034 - 0.13)	0.107 (0.076 - 0.15)

HbA1c of 7% or greater is considered as a positive test indicating poor glycemic control

(PPV= positive predictive value, NPV= negative predictive value, LR+ = positive likelihood ratio, LR- = negative likelihood ratio).

The device failure rate of the index tests was on four occasions with the SD A1c device, and on 11 occasions with Hemocue A1c device. We encountered 14 test failures with SD A1c device and 12 test failures with Hemocue A1c device. We could perform the test after using a new test strip in all these 26 situations. The test failures for the SDA1c device occurred at median ambient room temperature of 35 degrees Celsius (Range 28-35 degrees), and with Hemocue A1c device at median temperature of 36 degree Celsius (Range 35 to 37 degrees). However the test non-failure events (or test success events) also occurred at the same temperature (median 37 degrees C (range 25-42 degrees) for SD A1c) and median 36 degrees C (range 25-42 degrees C) for Hemocue A1c device. The mean number of test strips used to perform single test was 1.20 with SD device and 1.19 with Hemocue A1c device.

Discussion

In the current study we demonstrated that both techniques for point-of-care estimation of HbA1c levels were comparable to the reference standard. The current study is one of the largest and only such work from developing world. We encountered more device failures with the Hemocue device, and comparable test failures with both the devices. This provides us with important insights about performance of point-of-care tests in actual field conditions.

Our diagnostic study included those participants who would have received the tests in actual clinical practice. Most participants in our study were middle-aged men with uncontrolled T1DM or T2DM. These demographics are comparable to previous studies in terms of age, but had a lower representation of women. (17, 21, 22) The mean HbA1c level by reference standard in our study was 8.03% (SD 2.02), higher than in previous studies. (1, 2) These differences are a reflection of poor glycemic control in a developing country setting. Since there was a greater variation in the HbA1c values in our study, it has a potential to bias diagnostic accuracy estimates towards the null, as compared to the studies that included participants with lower mean HbA1c values. Despite this only 2.3% and 4.8% values were outside the two-standard deviation in the Bland-Altmann plot for SD and Hemocue A1c device respectively. This variation is comparable to previously reported studies. (22, 23) Previous HbA1c POC studies are listed in Table 4.

There was a difference in diagnostic accuracy estimates in the two assays evaluated in our study. While Hemocue A1c assay had a higher sensitivity and lower specificity, SD assay had a lower sensitivity but a higher specificity. These differences were observed as diagnostic accuracy was evaluated at a clinically meaningful cut-off of 7%, a level used to classify patients with optimal glycemic control. While there is a more recent guideline that suggests different target levels for different individuals with diabetes mellitus, yet 7% is a benchmark we usually strive for.

Table 4: Comparative analysis of previous studies of point of care HbA1c

Author (Year)	Country	Participants	Index test(s)	Reference standard	Agreement	Reference
Marley (2015)	Australia	241	DCA 2000+ Seimens	Cobasintegra 800	Sn 73.7%; Sp 98.2% for HbA1c of 6.4%; Correlation coeficient 0.88; Mean difference -0.15%(-0.67 to 0.36%);	22
Vilar-del-campo (2014)	Spain	102	DCA 2000+ Seimens	HPLC	Correlation coeicient 0.97; Mean difference 0.024%	23
Knabel (2013)	US	40	Bayer Aic now	HPLC	Correlation coeficient 0.98, mean difference -0.55 to +0.55%	18

Peterson (2010)	US	88	Seimens DCA, Affinion, BioRad In2it	HPLC BioRadVar 2	Mean Difference Seimens 0.7%, Affinion 0.6%, BioRad 0%	25
Martin (2010)	France		BioRadInt 2	HPLC Variant 2	Correlation 0.97;	24
Arrendale (2008)	US	70	Bayer A1c now	HPLC	Correlation 0.89	19
Martin (2007)	Australia	88	DCA (Siemens)	HPLC	Correlation 0.99, Mean Difference <0.01%	17
Sicard (2007)	US	23	Bayer A1c now	HPLC	Correlation coeficient 0.75	21

Immunoassays: Seimens DCA, A1c now

Borate affinity assays: BioRad Int2it

These differences in the diagnostic accuracy estimates are due to small variations around the cut-off in both assay methods (SD assay with a mean 0.34 lower, and Hemocue A1c device with a mean 0.43 higher values) as compared to HPLC based measurements. For a clinician who is assessing poor glycemic control, a Hemocue A1c measurement of 7% or higher, is 81% predictive of similar result by HPLC in contrast to 92% predictiveness by SD assay (positive predictive value). In contrast if aim is to assess optimal glycemic control Hemocue A1c assay is 91% predictive in contrast to 85% by SD assay (negative predictive value). Overall both assays are similar as their AUCs in ROC analysis are similar. The overall test performances of both index tests in current study are also comparable to a study by Marley et.al (2015) from Australia. (22)

There was higher device failure with Hemocue A1c device in our study. Device failure is a condition when either the device does not switch on, or is unable to receive a test strip or cartridge. The Key reason for high device failure with Hemocue A1c device (11/114) was power failure, as this equipment operates only on running electricity and does not have a battery back-up. The principal reason for SD A1c device to fail was battery run-off. Availability of running electricity is a constraint, and longer battery life is an asset for any point-of-care device in a developing country setting. We encountered 14 test failures with SD A1c device and 12 test failures with Hemocue A1c device. Test failure is a condition where the device gives an error message after insertion of the test strip. We could perform the test after using a new test strip in all these 26 situations. The test failures were random and could not be explained by temperature and more parameters like humidity have to be taken into account in future studies. The test failure rate, and test-strip/cartridge wastage was similar for both devices. While both the manufacturers suggest performing the test below a room temperature of 28 degree Celsius, the ambient room temperatures

were higher than this benchmark on most occasions. This is also typical of a tropical developing country scenario where POC tests are performed in non-temperature controlled environment. The room temperatures are above 28 degrees Celsius in most months of the year in our locality.

The current study was conducted in the same population that would have received the test in actual practice. The performance of the index tests and interpretation of its results was blinded and independent of the reference standard. Both the index tests and reference standard were performed using blood samples that were collected at the same time. We used clinically useful cut-offs for interpretation for our results. The study was conducted in two different facilities, where the ambient temperature ranged from 25-42 degrees and range of HbA1c tested was also wide ranging from 4.5 to 15.3%. Our study had certain limitations. We did not study the variant hemoglobin and absolute hemoglobin level of the patients, however this is unlikely to affect results of our study as prevalence of hemoglobinopathies is likely to be low. Our sample size was modest, yet this is one of the large studies conducted. Our testing environment was at variance with what would have been prescribed by the manufacturers, but this limitation is inherent, as actual temperature and humidity levels in developing country facilities are likely to be less than ideal.

Conclusion

Both the commercially available point of care HbA1c tests evaluated in this study (i.e. borate affinity or immunoassay) has similar results in comparison to the reference HPLC method. The sensitivity of both the point of care HbA1c tests are fairly good meaning that they can serve as acceptable alternate to time consuming HPLC method as a rapid screening tool. The higher positive predictive value imply we can fairly rely on the result of HbA1c > 7% for early titration of the drugs. The comparatively lower specificity and negative predictive values at HbA1c > 7% may make the clinicians watchful before changing the drugs. Both of these, point of care tests correlate well with the standard reference test with a wide range of temperature (25-42 degree Celsius). Temperature had no significant effect on device and test failures.

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Conflict of interest – Authors declare no conflict of interest.

Ethics approval- The study design was approved by the Institutional Human Ethics Committee of All India Institute of Medical Sciences, Bhopal(Ref: IHEC-LOP/2015/IM0056).

Informed consent- Participant Information Sheet in Hindi language was provided to each participant. All participants provided written informed consent prior to initiation of any study procedures.

Data sharing statement- Raw data of this study is not deposited in any public repository. However, anonymized raw data of this study would be available to academicians or researchers on reasonable request to corresponding author.

Author contributions: RJ conceived the study; RJ, APP and SK developed the protocol; SK and APP acquired data, APP, AJ and RJ analysed data and wrote first draft. All authors critically reviewed the first draft and provided inputs for its revisions.

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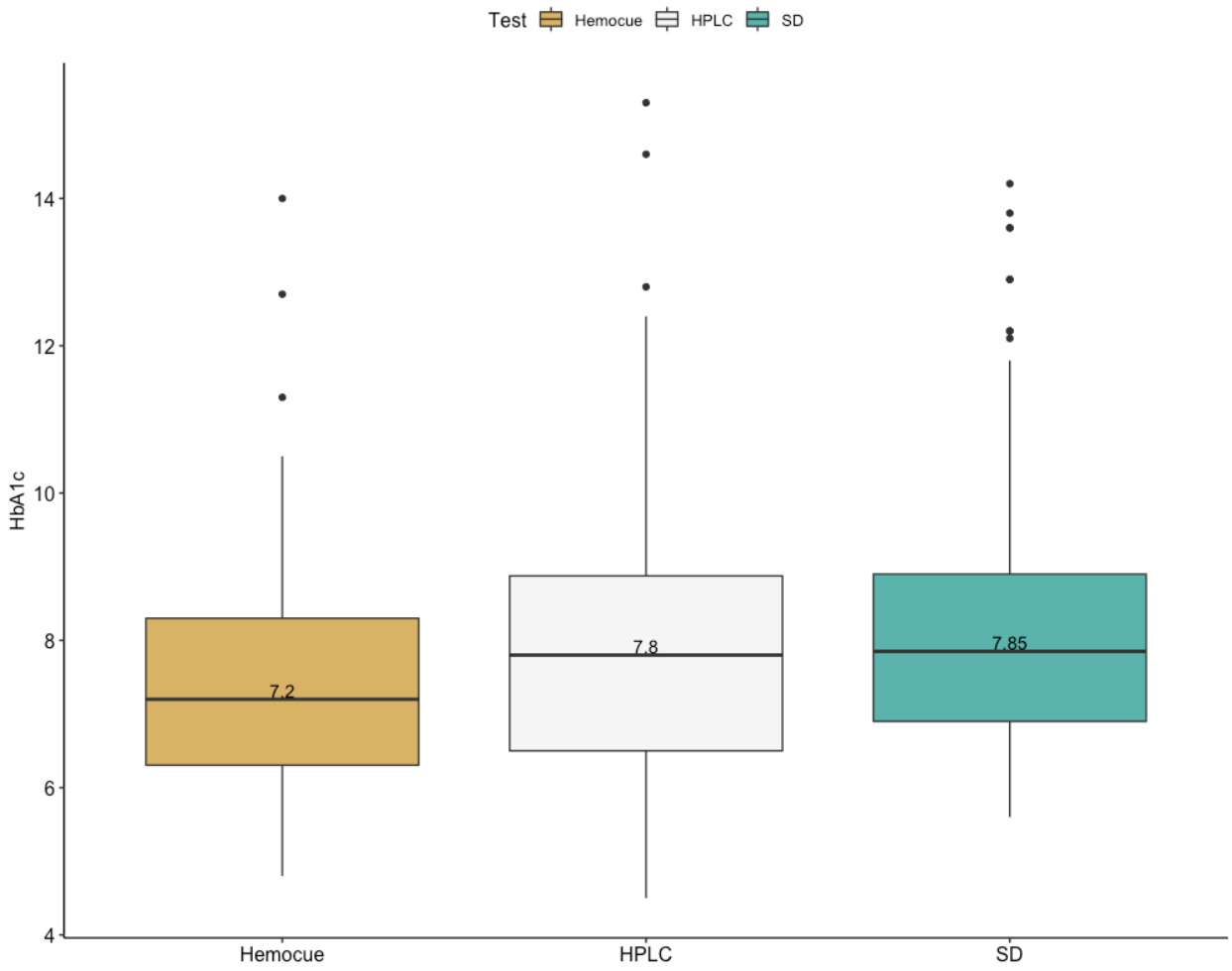
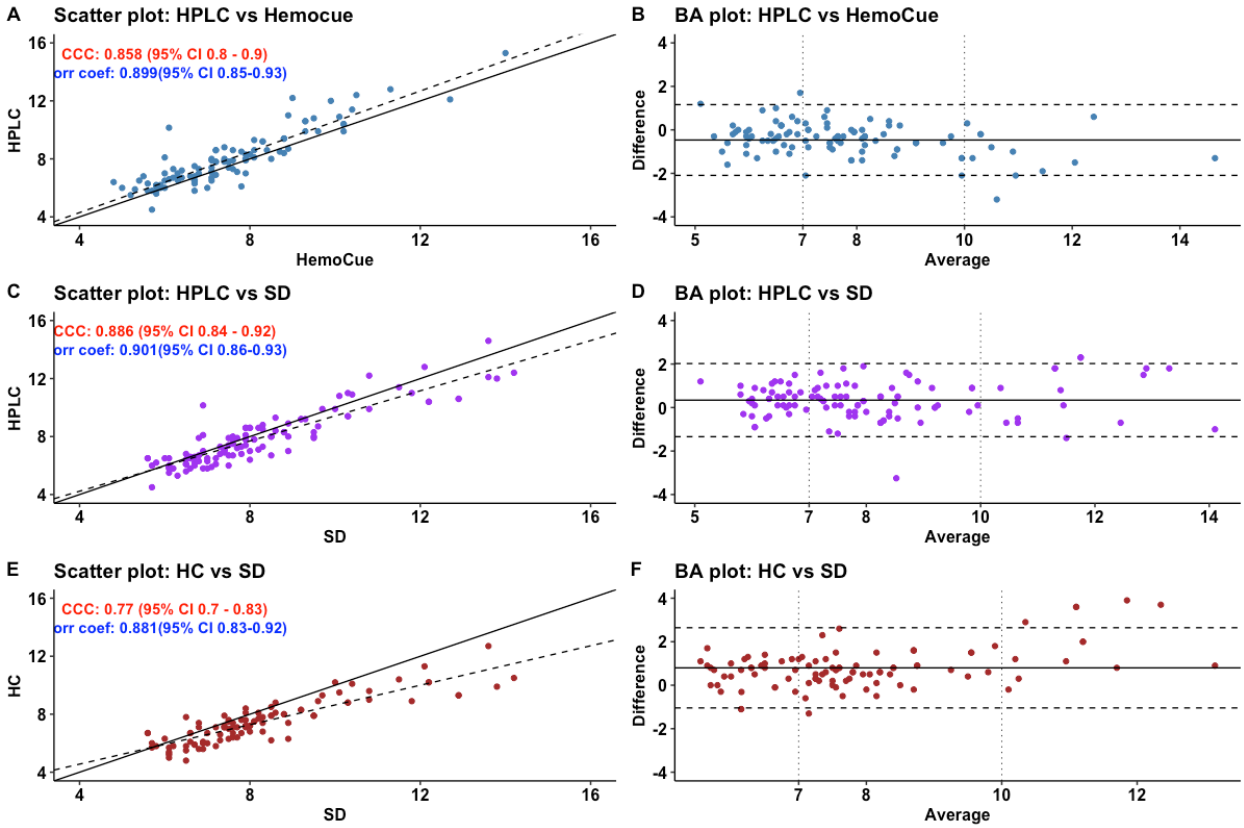
Figure 1: Box plot of the point of care HbA1c tests and reference standard.



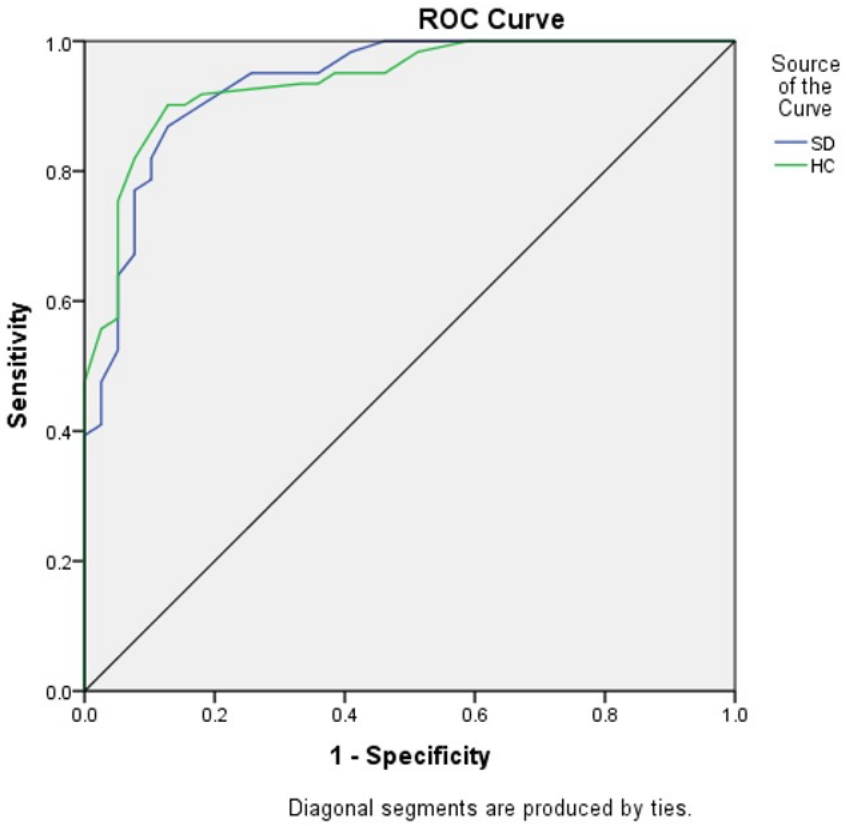
The median (inter-quartile range) HbA1c by SD device was 7.85 (6.9-8.9); Hemocue device was 7.2 (6.3-8.3) and by HPLC was 7.8 (6.5-8.9)

Figure 2: Scatter and Bland Altman plots HPLC vs Hemocue (A-B), HPLC vs SD (C-D) and Hemocue vs SD (E-F).



Scatter plots (A, C, E) are showing measurement by one method on X-axis and by other on Y-axis, for a good concordance their values should be clustered near 45 degree diagonal line. Solid line indicates this 45 degree line. Dashed line is fit line for linear regression analysis. Lin's Concordance Correlation Coefficient and Pearson's Correlation Coefficient are also displayed along with their 95% confidence intervals.
Bland Altman Plot (B, D, F) is used for visualizing the concordance between HbA1C levels estimated by two methods. Difference in HbA1C by two methods is plotted on y-axis and mean of HbA1C by two methods is plotted on x-axis. If both methods are concordant then it is expected that most of the observations would line around line of 0 differences (black, bold horizontal line). In case of discordance most values would lie beneath 2 standard deviations of mean differences on either side (dotted horizontal lines).

Figure 3: Area under the curve for SDA1c and Hemocue A1c devices for reference standard



HbA1c cut-off of 7%: The Area under the curve (AUC) for SDA1c device is 0.935 (95%CI 0.886-0.983), and for Hemocue device is 0.938 (95%CI 0.893-0.984).