AN EXAMINATION AND VERIFICATION OF URGENT BIOCHEMICAL ANALYTES PRODUCED BY LOCAL POINT-OF-CARE DEVICES COMPARED TO AN IN-HOUSE ANALYTICAL PLATFORM

Lauryn Bailey

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ABSTRACT

Background: The ABL90 Flex point-of-care devices used for creatinine and urea testing in the Resus and Majors departments at Portsmouth Hospitals University NHS Trust require verification for clinical use. These tests are crucial for diagnosing acute kidney injury and chronic kidney disease, conditions that heavily burden the NHS. This study aimed to evaluate the performance of urea and creatinine testing on the ABL90 Flex devices and compare them to the in-house Roche Cobas 8000 c702 platform. **Methods:** Precision testing (intra and inter) was conducted on the ABL90 Flex devices and the Roche Cobas 8000 c702 analyser. A paired sample comparison (n=50) was performed to identify significant differences between the in-house platform and the POCT devices. External quality controls were also assessed to evaluate the bias between the ABL90 Flex devices and other users. **Results:** The ABL90 Flex devices and the Roche Cobas 8000 c702 demonstrated acceptable precision, meeting manufacturers' claims and the Royal College of Pathologists of Australia specifications. External quality controls showed no significant bias compared to other devices in the same scheme. The sample comparison revealed a slight negative bias in ABL90 Flex results, except for creatinine on the Majors device, which exhibited a minor positive bias. Although statistically significant, these differences were not clinically significant. **Conclusion:** The ABL90 Flex urea and creatinine tests were approved for clinical use due to acceptable analytical performance. Continued clinician education is essential to ensure awareness of POCT limitations and differences from the in-house platform.

Keywords: creatinine, urea, point-of-care testing, verification, acute kidney injury

Abbreviations:

AKI – Acute kidney injury

CKD – Chronic kidney disease

CKD-EPI – Chronic kidney disease epidemiology collaboration

EQA – External Quality assurance

GFR – Glomerular Filtration Rate

IQC – Internal quality control

POCT – Point-of-care testing

SDI – Standard deviation index

SST – Serum separator tube

WEQAS – Wales external quality assurance scheme

1.0 Introduction

The adoption of point-of-care testing (POCT) is increasing in modern healthcare to meet the demand for rapid diagnostics amid rising healthcare pressures. However, POCT results can vary significantly from traditional laboratory results, impacting patient care. At Portsmouth Hospital University Trust, the Accident and Emergency Department plans to introduce urea and creatinine testing using the Radiometer ABL90 Flex blood gas analyser. As this is yet to be routine practice, verification is necessary to ensure that equipment and procedures meet required standards before routine implementation (Hunt, 2023).

Ammonia is produced from nitrogen generated by amino acid metabolism, which is neurotoxic and must be converted to a less harmful substance of urea for excretion, via the urea cycle in liver hepatocytes (**Figure 1**). Creatinine, another key marker, is a waste product resulting from the breakdown of creatine and creatine phosphate in muscle cells (Salazar, 2014). Creatine, synthesised from glycine, arginine, and methionine, converts to creatine phosphate, which donates a phosphate to adenosine diphosphate to regenerate adenosine triphosphate. Creatine phosphate is then degraded into creatinine (**Figure 2**).

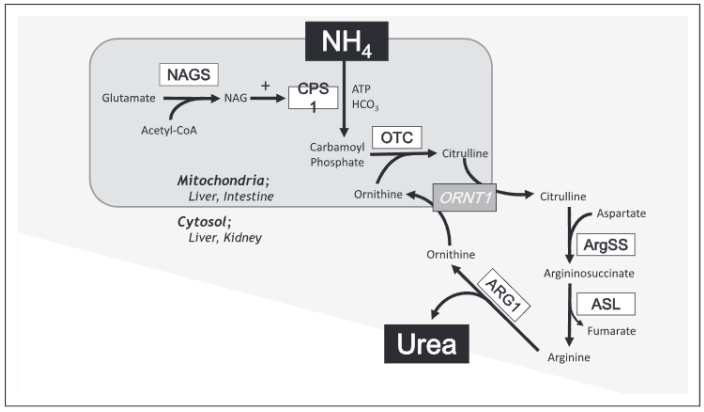

***Figure 1**: A diagram showing the process of the urea cycle (Long et al., 2023).*

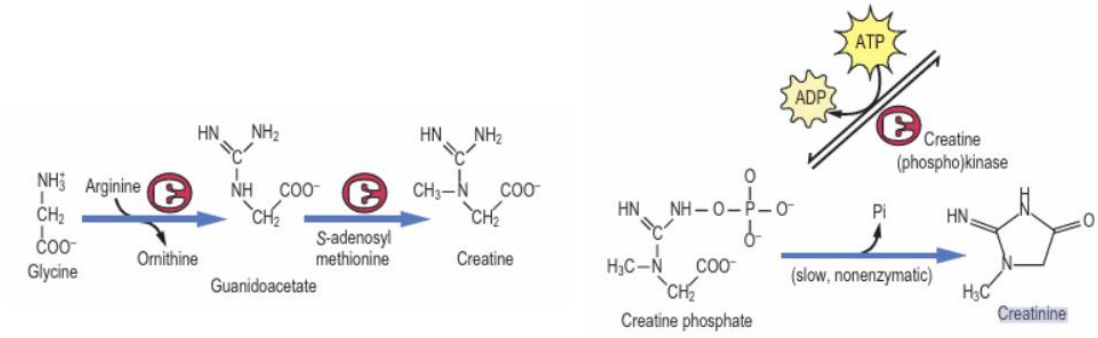

***Figure 2:** A diagram outlining the production of creatine and subsequent production of creatinine (Baynes & Dominiczak, 2018).*

The measurement of urea and creatinine allows clinicians to assess a patient's renal function as the kidneys primarily excrete nitrogenous waste products (Gounden et al., 2022). Chronic kidney disease (CKD) is marked by a progressive decline in renal clearance, often assessed by estimating the glomerular filtration rate (GFR). There are various methods for estimating GFR including the Cockcroft-Gault equation and the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation, which use factors such as age, race, sex, and serum creatinine levels (Gaitonde et al., 2017). Although serum urea is less commonly used for GFR estimation due to its sensitivity to diet and hydration status, it remains useful for identifying conditions like dehydration and liver disease, and for calculating the urea-to-creatinine ratio to distinguish between pre-renal and intrinsic acute kidney injury (AKI) (Marshall et al., 2016).

AKI is characterised by a rapid decline in renal function, which can result from factors such as hypovolaemia or septic shock. It is often asymptomatic, making early detection crucial for preventing progression to renal failure and reducing complications (Kurzhagen, 2020). Pre-renal AKI is caused by reduced renal blood flow due to factors such as chronic heart disease, which leads to a decreased GFR, highly elevated serum urea and high creatinine levels. In contrast, intrinsic AKI, due to renal tubular damage, also leads to elevated serum creatinine levels but with less pronounced increases in urea due to impaired reabsorption (Marshall et al., 2016).

AKI affects up to 70% of critically ill patients, with 40% of survivors developing CKD and 10% requiring lifelong dialysis or transplantation, imposing a significant financial burden on the NHS, estimated at £434-620 million annually. Early detection of AKI is critical to mitigate complications such as CKD. Tests for serum creatinine and urea can detect AKI days before significant damage occurs, underscoring their role in early diagnosis and reducing the NHS burden (Hall et al., 2018).

A retrospective cohort study in Southampton and South-West Hampshire revealed that 69% of 1076 newly diagnosed CKD patients died within 5.5 years, with 46% of these deaths attributed to cardiovascular causes. Mortality rates were 36 times higher in 16–49-year-olds compared to the general population (Kerr, 2012). This underscores the need for rapid renal function assessments. Implementing POCT could facilitate faster diagnoses and treatments,

potentially reducing complications, the need for long-term treatment, and inpatient stay durations, thus alleviating NHS burdens.

POCT conducted at the patient's bedside, provides faster results and requires less sample volume compared to traditional laboratory testing, facilitating quicker diagnoses and treatment decisions. However, POCT has its drawbacks, such as potential quality control issues due to non-laboratory-trained staff, higher costs, and lower analytical sensitivity (Lingervelder et al., 2021; Shaw, 2016).

The ABL90 Flex employs different measurement principles for urea and creatinine compared to the in-house Roche Cobas 8000 c702 analyser. The Roche Cobas 8000 c702 uses enzymatic spectrophotometry methods for both urea and creatinine. Creatinine measurement involves its conversion into quinone imine chromogen (**Figure 3**) (Roche Diagnostics, 2023), where the colour intensity formed is directly proportional to the creatinine concentration. Urea determination is based on the hydrolysis reaction (**Figure 4**), where for every mole of urea hydrolysed, two moles of NADH are oxidized to NAD+, making urea concentration directly proportional to the decrease in NADH concentration (Roche Diagnostics, 2022).

In contrast, the ABL90 Flex uses potentiometry to measure urea, utilising a voltmeter to measure the potential of an electrode chain and applying the Nernst equation to determine concentration. For creatinine, it employs a two-sensor amperometry system (Radiometer, 2018). These differing methodologies may result in potential discrepancies between POCT and in-house results.

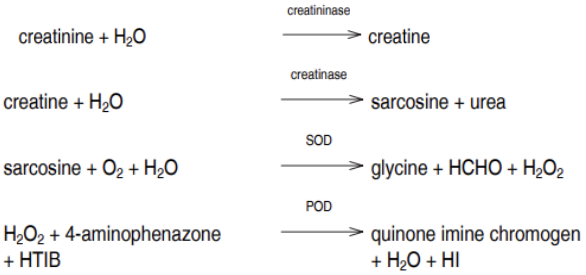

***Figure 3**: The reactions for the conversion of creatinine to quinone imine chromogen using the Roche Cobas 8000 c702 (Roche Diagnostics, 2023).*

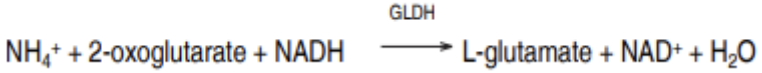

***Figure 4**: Urea hydrolysis reaction undertaken by the Roche Cobas 8000 c702 (Roche Diagnostics, 2022).*

2.0 Hypothesis and Aims

2.1 Hypothesis

H0: The performance of the two Radiometer ABL90 Flex meets the manufacturer's claims for urea and creatinine testing, operating within the Royal College of Pathologists of Australia's Analytical Performance Specifications, and shows no significant difference when compared to each other and when compared to the laboratory method.

H1: The performance of the two Radiometer ABL90 Flex devices do not meet the manufacturer's claims for urea and creatinine testing, does not operate within the Royal College of Pathologists of Australia's Analytical Performance Specifications and shows a significant difference when compared to each other and when compared to the laboratory method.

2.2 Aims

1. To execute a performance verification on two Radiometer ABL90 Flex POCT devices.
   Local verification procedures state that the introduction of a new procedure requires verification to ensure that the procedure is fit for purpose before becoming standard practice (Hunt, 2023).
2. Perform a test comparison study between the two ABL90 Flex POCT devices and in-house laboratory methods.
   A comparison between the POCT devices and in-house laboratory analysers has not yet been assessed. This could be beneficial in understanding the accuracy and reliability of results and if the results could impact clinical decision-making.

This is a verification study assessing the performance of urea and creatinine on two Radiometer ABL90 Flex devices, named 'Resus' and 'Majors', and a result comparison for urea and creatinine produced on the ABL90 Flex devices compared to the in-house laboratory Roche Cobas 8000 c702.

3.0 Materials

3.1 Ethical Consideration

In September 2023, the School of Biomedical Sciences Ethical Filter Committee granted permission for this project to take place with the understanding that it was beneficial to service improvement. No further ethical approval was required from Portsmouth Hospitals

University NHS Trust as the project was proposed in line with local verification/validation protocols and the Human Tissue Act. Furthermore, no additional blood draws were needed outside of required patient care and all patient data was anonymised.

3.2 Sample Collection

Samples were collected as part of routine care from patients in the Majors and Resus wards. These samples were then tested on the radiometer ABL90 Flex. All samples were tested for urea and creatinine, but these results were not released to the user for clinical use. As per normal clinical care, paired serum samples were also sent to the laboratory via an air tube transport system for in-house biochemistry testing and were processed as per local procedures (Steere, 2023). The samples were then tested for the investigations requested by the ward staff within 1 hour of receipt.

3.3 Reagents, Consumables, and Equipment

POCT

The testing of patient samples and internal quality controls (IQCs) was undertaken on two Radiometer ABL90 Flex devices, ‘Resus’ and ‘Majors’. All consumables were within their expiry date. ABL90 Flex SP90 Ki solution packs containing built-in IQCs are programmed to automatically run every 8 hours. The packs contain built-in calibrators that are used to calibrate the sensors every 24 hours. The IQC program was used to verify the running status and precision of the two devices. ABL90 electrodes including the Flex Sensor Cassette Packs SC90 and SC90 Ki were to measure each of the parameters (Radiometer Medical, 2018). SafePICO70 syringes were used to collect patient samples.

In-house

The testing of patient samples and IQC was undertaken using one Roche Cobas 8000 c702 clinical chemistry module. All consumables were within their expiry date. Samples and IQC were run as per local procedures. Urea and creatinine are UKAS ISO 15189 accredited tests within this laboratory. BD vacutainer serum separator tubes (SSTs) were used to collect patient samples and were centrifuged at 3500rpm for 10 minutes using a Thermo Scientific Sorvall ST16R Centrifuge. The reagent packs Roche CREP2 and Roche UREAL were used for creatinine and urea determinations. Roche CREP2 uses enzymatic methodology (Roche Diagnostics, 2023) whereas Roche UREAL is a kinetic test (Roche Diagnostics, 2022). The Roche calibrator for automated systems was run alongside deionised water in a Hitachi 5ml sample cup to create a two-point calibration curve. The performance of the urea and creatinine testing was then verified using levels 1 and 3 of Technopath multichem S plus quality controls.

4.0 Methodology

4.1 Intra and Inter Assay – Precision Assessment

Intra and inter-assay precision was assessed for both the 'Resus' and 'Majors' Radiometer ABL90 FLEX devices and the Roche Cobas 8000 c702. Intra precision was assessed by running multiple replicates (n=20) of three levels of ABL90 Flex SP90 Ki solution pack built-in IQCs on the two ABL90 Flex devices, and two levels of Technopath multichem S plus on the Roche Cobas 8000 c702. Inter-precision was assessed by running three levels of ABL90 Flex SP90 Ki solution pack built-in IQCs, and two levels of Technopath multichem S plus on the Roche Cobas 8000 c702 over 7 days (total n=20).

4.2 EQA – Bias Assessment

WEQAS samples (n=6) were run on each ABL90 FLEX and the data from the two distributions (June and July 2024) of WEQAS external quality control were retrieved for comparison.

4.3 Sample results

Patient results from December 2023 and January 2024 were downloaded from the 'Majors' and 'Resus' ABL90 Flex devices and supplied in a Microsoft Excel 365 workbook (version 2302). This data was then used alongside the laboratory information management system APEX, which is used for in-house test requests and results, to collate paired results for POCT and in-house testing over the analytical testing ranges for both creatinine and urea (n=50), ensuring that the difference between draw times did not exceed 4 hours. Exclusion criteria included: patients who have factors that invalidate the calculation of estimated GFR, those under the age of 18, those who were pregnant, and amputees.

4.4 Statistics and Data Collection

The data from the IQC inter and intra-assay runs, EQA data, and paired patient results were entered into a Microsoft Excel 365 workbook (version 2302). The paired patient results were then transferred into an ACB statistical analysis sheet (version 6.67 18-07-19) within a Microsoft Excel 365 (version 2302) to perform a series of statistical tests such as a t-test, Wilcoxon signed rank test, Bland-Altman plot, and Deming regression. Each set of data for each analyte for the different POCT devices was entered into different files (e.g., Urea on Majors POCT device, Creatinine on Majors POCT). A significance level of p-value = <0.05 was used to determine a significant statistical difference.

5.0 Results

5.1 Precision of Urea and Creatinine

Inter-assay and intra-assay IQC results were obtained from each device for each analyte (n=20). The inter-assay results were obtained over at least 5 days whereas the intra-assay results were obtained in immediate succession of each other (**Appendices 1-6**). The mean, standard deviation, range, and coefficient of variation were calculated for each (**Tables 1-4**).

***Table 1**: The calculated mean, standard deviation (SD), coefficient of variation (CV), and range for the inter-assay and intra-assay IQC results for urea from the POCT ABL90 Flex devices in Resus and Majors.*

	Resus ABL90 Flex Urea IQC Results (mmol/L)						Majors ABL90 Flex Urea IQC Results (mmol/L)					
	Inter-assay			Intra-assay			Inter-assay			Intra-assay		
	A	B	C	A	B	C	A	B	C	A	B	C
Mean	-0.10	15.56	5.54	-0.10	16.08	5.85	-0.10	15.93	5.54	-0.10	16.59	5.90
SD	N/A	0.52	0.21	N/A	0.35	0.07	N/A	0.32	0.14	N/A	0.24	0.12
CV (%)	N/A	3.32	3.86	N/A	2.15	1.17	N/A	2.03	2.57	N/A	1.45	2.09
Range	0.00	1.90	0.90	0.00	1.30	0.20	0.00	1.10	0.40	0.00	0.90	0.10

***Table 2**: The calculated mean, standard deviation (SD), coefficient of variation (CV), and range for the inter-assay and intra-assay IQC results for creatinine from the POCT ABL90 Flex devices in Resus and Majors.*

	Resus ABL90 Flex Creatinine IQC Results (umol/L)						Majors ABL90 Flex Creatinine IQC Results (umol/L)					
	Inter-assay			Intra-assay			Inter-assay			Intra-assay		
	A	B	C	A	B	C	A	B	C	A	B	C
Mean	1.90	65.55	418.40	2.00	65.70	431.90	2.00	65.70	431.90	2.00	64.55	420.35
SD	0.31	2.14	13.16	0.00	1.42	3.16	0.00	1.42	3.16	0.00	1.05	6.17
CV (%)	16.20	3.26	3.14	0.00	2.16	0.73	0.00	2.16	0.73	0.00	1.63	1.47
Range	1.00	8.00	52.00	0.00	4.00	14.00	0.00	4.00	14.00	0.00	3.00	23.00

***Table 3**: The calculated mean, standard deviation (SD), coefficient of variation (CV), and range for the inter-assay and intra-assay IQC results for urea from the in-house Roche Cobas 8000 c702.*

	Roche Cobas 8000 c702 Urea IQC Results (mmol/L)			
	Inter-assay		Intra-assay	
	Level 1	Level 3	Level 1	Level 3
Mean	2.81	21.44	2.81	21.50
SD	0.07	0.44	0.05	0.34
CV (%)	2.56	2.07	1.82	1.56
Range	0.20	1.90	0.20	1.10

***Table 4**: The calculated mean, standard deviation (SD), coefficient of variation (CV), and range for the inter-assay and intra-assay IQC results for creatinine from the in-house Roche Cobas 8000 c702.*

	Roche Cobas 8000 c702 Creatinine IQC Results (umol/L)			
	Inter-assay		Intra-assay	
	Level 1	Level 3	Level 1	Level 3
Mean	60.96	518.31	61.97	527.31
SD	0.80	4.91	0.69	3.56
CV (%)	1.31	0.95	1.12	0.68
Range	2.60	15.50	2.40	15.30

These results were compared to the Analytical Performance Specifications published by The Royal College of Pathologists of Australia (2022) to determine if the devices perform to an acceptable level. The acceptable limits range are the same for both blood gas and serum chemistry testing and are shown (**Table 5**).

Table 5: The acceptable limits for blood gas and serum creatinine and urea as supplied by The Royal College of Pathologists Australia (2022).

	Lower limit	Upper limit
Creatinine	±8 ≤100umol/L	±8% >100umol/L
Urea	±0.5 ≤4.0mmol/L	±12% >4.0mmol/L

5.2 Sample Comparison

Another aim of this study was to undertake a sample comparison between the POCT ABL90 Flex and the in-house Roche Cobas 8000 c702. The sample comparison data is not normally distributed, and non-parametric methods of statistical analysis were required. A Wilcoxon signed-rank test was performed for each analyte and POCT device in comparison to the in-house analyser to determine if there is a significant difference (*p*-value <0.05) between platforms. The average truncated relative difference was also calculated (**Table 6**). These results show a significant difference between the Resus POCT device for both analytes and the in-house platform as well as between the in-house platform and the Majors POCT for urea as these have a *p*-value of <0.05. The average truncated relative difference also shows that these POCT tests are running at lower values than that of the in-house platform. However, the Majors POCT device shows no statistically significant difference, as shown by the *p*-value of 0.633, and the average truncated relative difference shows slightly higher values compared to the in-house platform (**Figure 5)** Bland-Altman graphs were used to visualise the relative differences between the in-house and POCT platforms (**Figures 6-9)**.

***Table 6**: The calculated p-values following a Wilcoxon signed-rank test and average truncated relative difference (%) for each POCT ABL90 Flex in comparison to the Roche Cobas 8000 c702*

Device	Analyte	*p*-value	Average Truncated Relative Difference (%)
Majors	Urea	0.001	-7.28
	Creatinine	0.633	0.44
Resus	Urea	0.006	-5.54
	Creatinine	0.023	-2.12

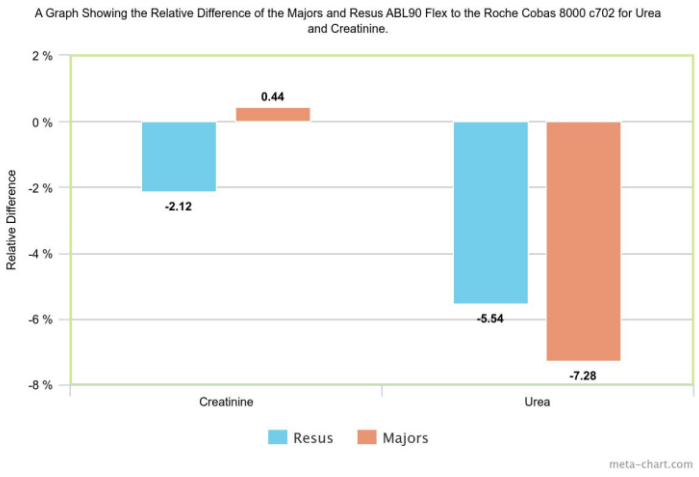

Figure 1: A graph showing the relative difference of the Majors and Resus ABL90 Flex to the Roche Cobas 8000 c702 for urea and creatinine.

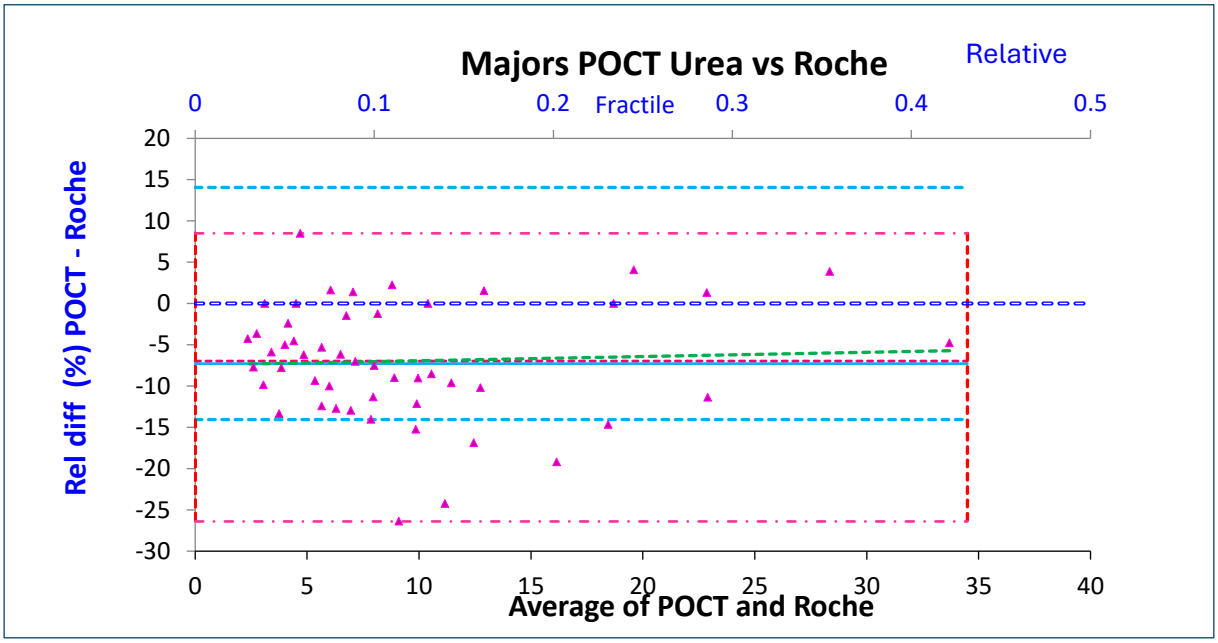

Figure 6: A Bland-Altman relative difference chart showing a mostly constant negative bias in urea results for the Majors POCT ABL90 Flex when compared to the Roche Cobas 8000 c702.

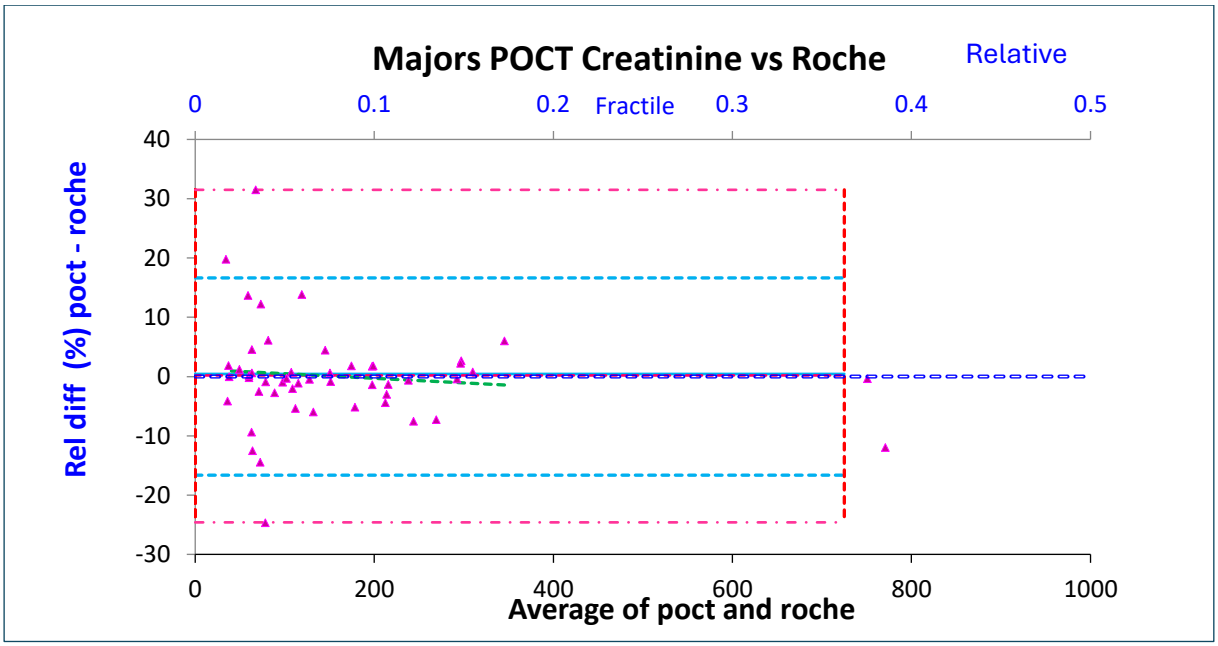

Figure 7: A Bland-Altman relative difference chart showing the similarity in creatinine results for the Majors POCT ABL90 Flex and the in-house Roche Cobas 8000 c702

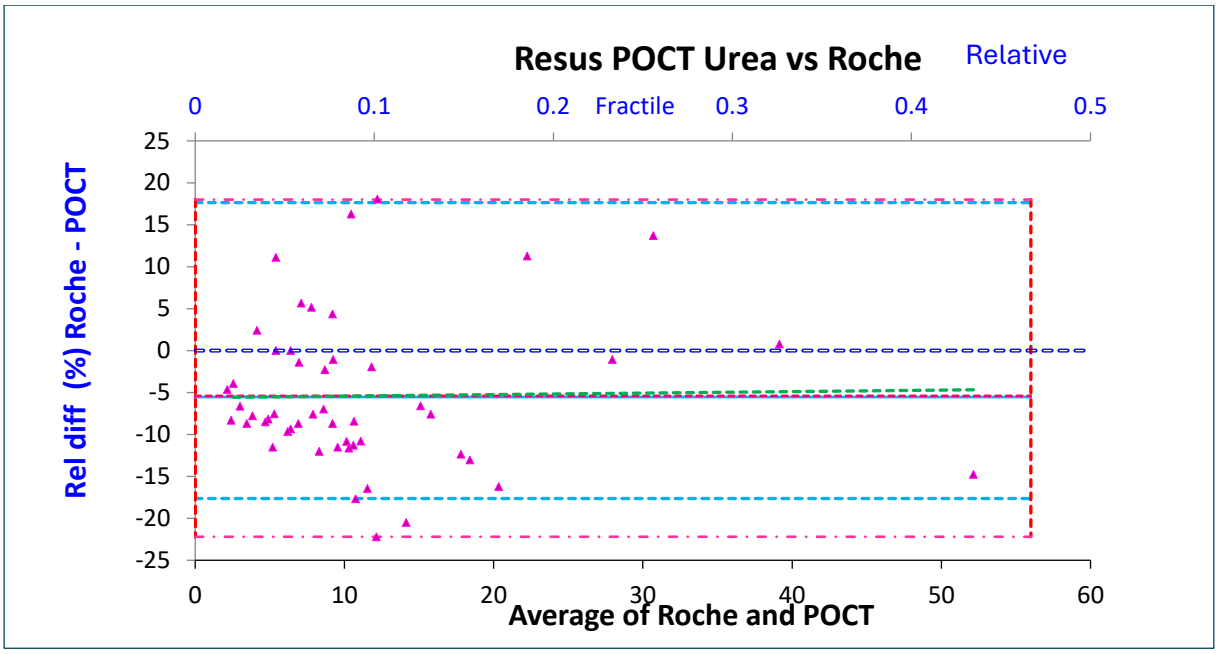

Figure 8: A Bland-Altman relative difference chart showing a mostly negative constant bias in urea results for the Resus POCT ABL90 Flex when compared to the Roche Cobas 8000 c702.

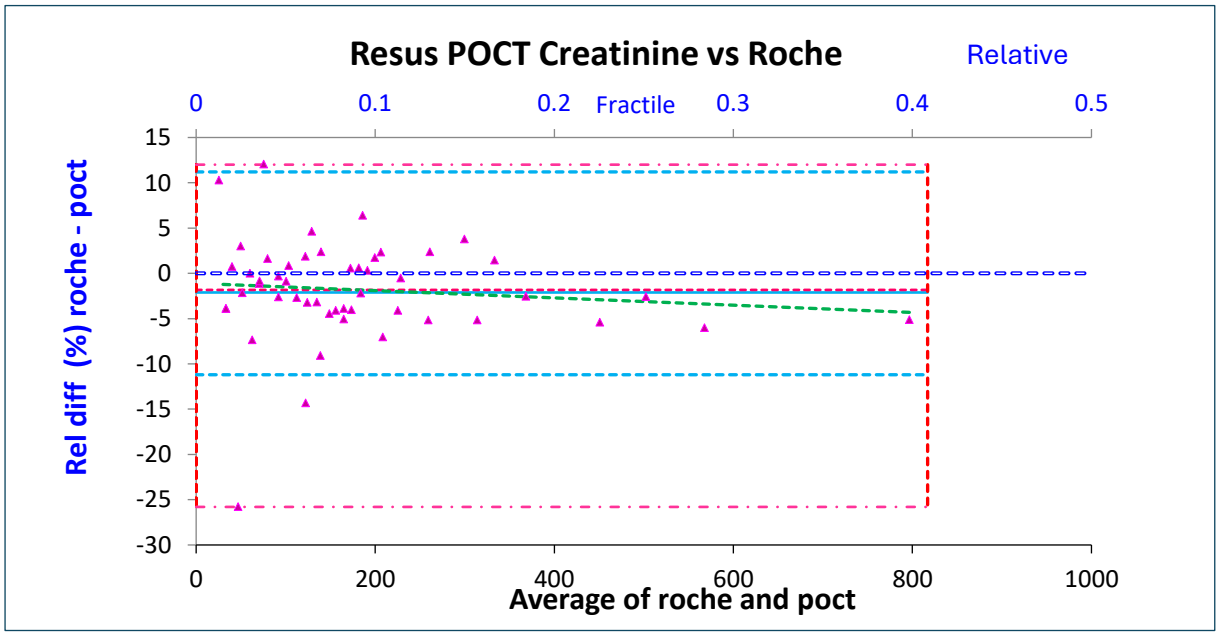

Figure 9: A Bland-Altman relative difference chart showing a slight mostly negative bias in creatinine results for the Resus POCT ABL90 Flex when compared to the Roche Cobas 8000 c702.

5.3 External Quality Control

The results for WEQAS (Wales External Quality Assessment Scheme) external quality assurance (EQA) samples from December 2023 and January 2024 for each POCT device were used to assess the bias between other WEQAS group members using the same equipment. Reports are returned for each EQA distribution providing a standard deviation index (SDI) for each sample, test, and device, as well as an overall average SDI for each test. The acceptable SDI ranges are provided by WEQAS (2022) and state that an SDI of less than 1 is good and less than 2 is acceptable, however, greater than 2 is deemed unacceptable. The EQA results along with their reported SDIs (**Tables 7-10**).

Table 7: A table showing the results for two distributions of WEQAS EQA tested for urea on the Majors ABL90 Flex POCT device with their target and reported SDI as well as the overall mean SDI for each distribution.

Majors Urea	TARGET	RESULT	SDI
BG0623 - 1	10.37	9.7	0.62
BG0623 - 2	18.24	17.6	0.38
BG0623 - 3	6.01	5.4	0.43
BG0623 - Overall			0.48
BG0723 - 1	6.07	5.3	0.26
BG0723 - 2	14.67	14.1	0.47
BG0723 - 3	23.37	22.4	0.53
BG0723 - Overall			0.42

Table 7: A table showing the results for two distributions of WEQAS EQA tested for creatinine on the Majors ABL90 Flex POCT device with their target and reported SDI as well as the overall mean SDI for each distribution.

Majors Creatinine	TARGET	RESULT	SDI
BG0623 - 1	207.6	142	0.8
BG0623 - 2	379.4	279	0.94
BG0623 - 3	117.5	98	0.3
BG0623 - Overall			0.68
BG0723 - 1	116.7	98	-0.76
BG0723 - 2	296.4	236	-0.4
BG0723 - 3	553.8	442	-0.19
BG0723 - Overall			0.45

Table 8: A table showing the results for two distributions of WEQAS EQA tested for urea on the Resus ABL90 Flex POCT device with their target and reported SDI as well as the overall mean SDI for each distribution.

Resus Urea	TARGET	RESULT	SDI
BG0623 - 1	10.37	9.7	0.49
BG0623 - 2	18.24	17.6	0.38
BG0623 - 3	6.01	5.4	0.43
BG0623 - Overall			0.44
BG0723 - 1	6.07	5.1	-0.17
BG0723 - 2	14.67	13.8	0.21
BG0723 - 3	23.37	22	0.31
BG0723 - Overall			0.23

Table 9: A table showing the results for two distributions of WEQAS EQA tested for creatinine on the Resus ABL90 Flex POCT device with their target and reported SDI as well as the overall mean SDI for each distribution.

Resus Creatinine	TARGET	RESULT	SDI
BG0623 - 1	207.6	182	-3.01
BG0623 - 2	379.4	330	-1.84
BG0623 - 3	117.5	108	-0.94
BG0623 - Overall			1.93
BG0723 - 1	116.7	105	0.11
BG0723 - 2	296.4	242	0.03
BG0723 - 3	553.8	467	0.63
BG0723 - Overall			0.25

6.0 Discussion

6.1 Precision of Urea and Creatinine

The precision of urea and creatinine measurements on the POCT devices was evaluated to verify whether the results aligned with the manufacturer's performance claims for these analysers. This assessment is crucial in determining the suitability of the device for routine use and in validating its performance. Additionally, precision was assessed on the in-house Roche Cobas 8000 c702 analyser, as the POCT devices were being compared to this system. Precision is crucial, especially in the context of diagnosing AKIs using the NHS algorithm, which relies on accurate serum creatinine measurements over time (Sawhney *et al*., 2015). The NHS AKI algorithm detects kidney injury by comparing current creatinine levels with previous results, and even small inaccuracies can lead to misdiagnosis or missed diagnoses. If a POCT device produces imprecise results, it could incorrectly trigger or miss an AKI alert, leading to inappropriate treatment decisions. Therefore, ensuring precision in these devices is essential for accurate and effective patient care.

The calculated ranges and CVs were compared against standards published by The Royal College of Pathologists of Australia (2022) (**Table 5**), and it was found that each test for each POCT device and the Roche analyser fell within the acceptable range. These findings suggest that all analysers are operating with an acceptable level of precision, supporting the section of the hypothesis that the Radiometer ABL90 Flex meets the specifications of The Royal College of Pathologists Australia and is capable of accurately performing creatinine and urea tests. Furthermore, the results confirm the end section of the hypothesis, a comparison between POCT and in-house testing, can be conducted as the in-house platform is performing within acceptable standards.

The manufacturer's precision guidance also needed to be assessed to see if the performance of the analysers meets the manufacturer's claims. Roche Diagnostics performed precision tests that can be used to assess the Roche Cobas 8000 c702. The CV range is reported as 0.8-1.1% for creatinine (Roche Diagnostics, 2023) and 0.7-1.2% for urea (Roche Diagnostics, 2022). This shows that the Roche Cobas 8000 c702 is not performing in line with manufacturer claims, supporting the alternative hypothesis. However, it can be noted that performing within the standards published by The Royal College of Pathologists of Australia (2022) may be a more suitable method of determining performance as these specifications acknowledge that CVs can appear higher at lower values, and therefore publish low-value precision specifications as a range between measurable values rather than using CV. Furthermore, the Roche Diagnostics precision tests may not be the most suitable method for establishing precision in clinical practice as these tests were performed in a sterile research lab as opposed to a routine clinical laboratory. This could lower the chance of Roche Diagnostics encountering pre-analytical errors that can be seen in clinical testing, resulting in a level of precision that may not be achievable in practice. Additionally, the IQCs used in Roche Diagnostic testing were manufactured by Roche. It is a UKAS requirement to adhere to ISO 15189 which states that conflicts of interest must be avoided to remain impartial, meaning that IQCs within the laboratory must be third party and have no affiliation with Roche Diagnostics. This means that different IQCs were used in the Roche Diagnostics precision testing than were used in this study. These IQCs may have different commutability.

Radiometer Medical (2018) completed similar precision runs on each of their analytes across the testing range and released the results. The CV range is 2.6-4.9% for urea and 3.5-67%

for creatinine. This shows that the two POCT devices are working within the manufacturer's claims except for the low-level IQCs. This could be due to this level of IQC being below the limit of quantification.

A notable concern with this part of the study is that the IQC samples used for the Radiometer ABL90 Flex do not cover the entire reportable range for either test. The reportable range is 2-42 mmol/L for urea and 35-900 µmol/L for creatinine (Radiometer Medical, 2018). However, the highest IQC level is approximately 16 mmol/L for urea and 425 µmol/L for creatinine, leaving the upper end of the reportable ranges untested. This means that potential issues affecting the higher end of the clinical range may go undetected, leading to erroneous results. For instance, the phoning limit for urea is set at ≥30 mmol/L, yet the highest IQC level tested is around 16 mmol/L (Royal College of Pathologists, 2017). Elevated urea levels can be indicative of serious conditions such as severe dehydration and gastrointestinal bleeding (Tomizawa, 2015). Inaccurate reporting of high urea levels could result in failure to identify these conditions, improper patient triage, and potentially discharging patients without necessary care. Additionally, the range of indication is 1-50 mmol/L for urea and 10-1800 µmol/L for creatinine (Radiometer Medical, 2018), indicating that the lowest IQC levels fall outside the analyser's limits of quantification. As a result, these tests cannot be considered reliable, as they fall outside the manufacturer's indicated range and therefore do not provide valid or reportable data. It is recommended that new POCT IQCs be introduced, and this section of the study repeated to obtain more meaningful and valid measurements that can assess precision across the entire reportable range.

6.2 Sample Comparison

When compared to the Roche Cobas 8000 c702, the Majors ABL90 Flex shows a negative bias for urea testing. The relative differences range from -26.4% to 8.5% with an average relative difference of -7.28%. This is within the range of ±12% specified by The Royal College of Pathologists of Australia (2022). The relative percentage difference Bland-Altman plot is suggestive of a constant negative bias, showing minimal variation in average relative difference across the range of values (**Figure 6**). The Wilcoxon signed-rank test resulted in a *p*-value of 0.001 for urea, showing a statistically significant difference between the two analysers. Alternatively, creatinine testing on the Majors ABL90 Flex showed a slight positive bias when compared to the Roche Cobas 8000 c702. The relative differences range from -24.6% to 31.5% with an average relative difference of 0.44%. This is within the range of ±8% specified by The Royal College of Pathologists of Australia (2022) The relative percentage

difference Bland-Altman plot is suggestive of a slight constant positive bias, showing minimal variation in average relative difference across the range of values (**Figure 7**). The Wilcoxon signed-rank test resulted in a *p*-value of 0.663 for creatinine, showing no statistically significant difference between the two analysers. Creatinine testing on the Majors ABL90 Flex was the only test that showed a positive bias and no statistically significant difference.

When compared to the Roche Cobas 8000 c702, the Resus ABL90 Flex shows a negative bias for urea testing. The relative differences range from -22.2% to 18.0 with an average relative difference of -5.54%. This is within the range of ±12% specified by The Royal College of Pathologists of Australia (2022). The relative percentage difference Bland-Altman plot is suggestive of a constant negative bias, showing minimal variation in average relative difference across the range of values (**Figure 7**). The Wilcoxon signed-rank test resulted in a *p*-value of 0.006 for urea, showing a statistically significant difference between the two analysers. Creatinine testing on the Resus ABL90 Flex also showed a negative bias when compared to the Roche Cobas 8000 c702. The relative differences range from -25.8% to 12.0% with an average relative difference of -2.12%. This is within the range of ±8% specified by The Royal College of Pathologists of Australia (2022). The relative percentage difference Bland-Altman plot is suggestive of a constant negative bias, showing minimal variation in average relative difference across the range of values (**Figure 8**). The Wilcoxon signed-rank test resulted in a *p*-value of 0.023 for creatinine, showing there is a statistically significant difference between the POCT and in-house analysers.

The creatinine results reveal a slight increase in relative percentage difference at the upper end of the range. It is important to consider whether this increase has clinical significance by referring to the current reference ranges for creatinine. The clinical reference range for creatinine on the Roche Cobas 8000 c702 at the time of this study was 59-104 µmol/L, with any results ≥354 µmol/L requiring urgent phoning (Wilkins, 2022). Given this context, the rise in percentage difference at the higher end of the range is less likely to have a significant clinical impact, as all results at this level would be treated with the same level of urgency.

The observed relative differences and *p*-values should be clinically assessed within the context of POCT to determine their impact on patient care. Despite statistically significant differences, it is crucial that all POCT results are supplemented by confirmatory laboratory testing. Although POCT may yield lower results, its initial use remains valuable for identifying

patients at risk of AKI, CKD, and other complications, enabling early intervention. Clinicians must be trained to understand the importance of confirmatory testing and the potential for sample variation. Given these differences, creatinine and urea testing may be best suited for emergency settings to promptly identify patients with low eGFR, which is critical for determining treatment options, such as the suitability for contrast imaging due to the renal excretion and neurotoxicity of contrast media (Takura *et al*., 2023). However, in settings like dialysis units, where creatinine levels are closely monitored to guide treatment, these differences may significantly impact patient care making them unsuitable for use in this location.

It is crucial to investigate why the Majors' POCT device exhibits a different bias for creatinine compared to the Resus POCT device. Several factors may contribute to this discrepancy, including the fact that the Majors' POCT device is in a different location from the Resus device. This could suggest that human error may be a contributing factor, particularly if staff are assigned to specific areas and predominantly use only one of the POCT devices. Inadequate training or incomplete competency assessments could lead to discrepancies in results between the devices. Wiencek and Nichols (2016) highlight that POCT is particularly prone to human error, as non-laboratory staff are typically the primary users, which can lead to lapses in maintenance, cleaning, and checking reagent expiration dates. Additionally, Portsmouth Hospital University NHS Trust has been under increasing pressure, with emergency wards often fully occupied, leading to stretched staff resources (Taylor, 2022). These pressures could result in rushed POCT procedures and insufficient time or resources for proper staff training. However, if human error were the primary cause, it could be expected to see discrepancies in the urea results between the POCT analysers as well. Environmental factors, such as temperature differences between the locations of the devices, might also be considered, though there is no evidence from the manufacturer (Radiometer) to suggest that creatinine is more susceptible to environmental influences than urea (Radiometer Medical, 2018).

It could be argued that the location of the devices might contribute to variations in daily throughput, given that Resus comprises only four patient bays. Consequently, the Majors POCT device is likely to conduct a significantly higher volume of tests. The sensor cassette of the device is limited to a predetermined number of tests before requiring replacement, which suggests that it might be replaced more frequently in the Majors ABL90 Flex. This increased frequency of replacement necessitates more regular maintenance. Consequently,

it is plausible that the reagents in the Resus analyser could be older and more likely to cause issues compared to those on the Majors analyser, which might not undergo maintenance as frequently due to the less frequent necessity of sensor cassette changes. Such factors could contribute to discrepancies in the results obtained from the two analysers.

Another potential cause for the differences in creatinine results between the POCT devices could be poor calibration. However, this is unlikely. The devices are calibrated every 24 hours, and the sample results span two months. For the difference to persist consistently over this period, there would have to have been numerous poor calibrations. Additionally, if a calibration issue arises or if there is a significant discrepancy between calibration results, the analyser automatically blocks the test from running patient samples until the issue is resolved. Furthermore, the calibrators are integrated into the devices and are used for a variety of different tests. If poor calibration were the issue, it could also be expected to see differences in the results for urea, which has not been observed.

This difference between the two POCT analysers does not support the null hypothesis but instead supports the alternative hypothesis as there is a difference between the two POCT devices. This was further investigated by reviewing two distributions of EQA results.

6.3 External Quality Control

The overall SDI values provided in the reports from WEQAS indicate that the POCT devices are performing comparably to other devices within the same WEQAS scheme group. The overall SDI for creatinine on the Resus ABL90 Flex was 1.93, which meets WEQAS standards for acceptability. Additionally, the urea measurements on the Resus device, along with both tests on the Majors device, were deemed to be of 'good' quality.

In comparison to the sample comparison results, there appears to be little difference between ABL90 Flex devices within the scheme when looking at the SDIs, unlike the differences seen between them and the Roche Cobas 8000 c702 using *p*-values While this initially suggests satisfactory performance, the low SDIs could potentially result from variability among the ABL90 Flex devices themselves, leading to an expanded range for the SDIs. An example of this can be shown when looking at sample BG0623-2 for creatinine on the Majors device (**Table 8**). Despite having an SDI of 0.94 and being deemed as ‘good’, the

difference between the target value (379.4) and the result (279) is considerable. The difference between these results could be substantial enough to change a patient's AKI staging result from AKI 3 to a different stage, depending on their previous results (Sawhney *et al*., 2015). Furthermore, the results for creatinine on the Resus device could show how variance between the analysers affects the SDI. The difference between the target and the result for BG0623-1 is 25.6umol/L and the SDI is -3.01 which is deemed as an unacceptable difference. However, the difference between the target and the result for BG0623-2 is 49.4umol/L. Despite showing a larger variation, the SDI is -1.84 which is deemed acceptable. This suggests that, while comparing SDIs may provide some insight into how ABL90 Flex devices perform relative to one another, SDIs alone may not reliably indicate whether these devices meet acceptable standards for clinical testing, particularly as significant differences in results can have profound implications for patient care. In addition to potentially altering AKI staging outcomes, such discrepancies can influence whether clinical actions are taken based on the results. For instance, the target creatinine result of 379.4umol/L for the EQA sample BG0623-2 would typically prompt clinical action, as it exceeds the threshold set by the Royal College of Pathologists (2017). However, the measured results on both ABL90 Flex devices fell below this threshold, meaning that, had this been a patient result, it would not have triggered the necessary response, thereby highlighting the potential impact of these variations on patient care.

Although the overall SDI for creatinine on the Resus device is classified as acceptable, a closer examination of the individual SDIs for the three samples from the first distribution of EQA reveals variability in performance. Specifically, BG0623-1 was deemed unacceptable, BG0623-2 acceptable, and BG0623-3 good. This variability may be attributed to external factors influencing the results. As noted by Wiencek and Nichols (2016), POCT devices are primarily operated by non-laboratory-trained staff, who are often busy, which can result in lapses in required maintenance. Such lapses could lead to issues such as carryover between samples, potentially explaining the poor results for EQA BG0623-1 for creatinine on the Resus device. This issue would likely have a greater impact on EQA one, as it is typically run first in the batch; if a sample with particularly high results was processed immediately beforehand, it could disproportionately affect the first EQA, while subsequent EQAs would be less impacted as the inlet probe is washed with each sample. The difference between EQA one values for Resus creatinine cannot be explained by transportation or issues with the primary sample as this would impact the results obtained by the Majors POCT also.

It is noteworthy that the creatinine measurements on the Majors POCT device were reported with good SDI values, indicating that, despite differences in performance compared to the Resus POCT device, there is no significant deviation between creatinine results from the Majors device and those from the rest of the WEQAS scheme group, which includes the Resus. These points support the null hypothesis as it shows that there is no significant difference between the POCT devices, and the devices are performing as expected.

6.4 Existing Studies

Numerous published studies have explored similar areas to this study. For example, Pizarro Sánchez *et al*. (2020) conducted a verification of creatinine and urea measurements on an ABL90 Flex, comparing it with three laboratory analysers, including the Roche Cobas 8000 c702. They employed an allowable difference threshold of ±15.6% for urea and ±8.9% for creatinine. The ABL90 Flex results fell within these thresholds at clinical decision levels, leading to its verification for clinical practice. It was determined that differences below these thresholds had no impact on patient care. This suggests that, while differences between POCT devices and the in-house platform in this study exist, they may fall within a range that has a minimal impact on patient outcomes.

Similarly, Bargnoux *et al*. (2021) conducted a study comparing creatinine and urea measurements between the ABL90 Flex and the Roche Cobas 8000 c702, finding results consistent with those in this study. Both analysers demonstrated good precision, and it was observed that the ABL90 Flex exhibited a negative bias. If ABL90 Flex devices consistently run lower, this could explain the minimal difference in EQA results compared to other devices in the WEQAS scheme. Additionally, this study found that creatinine and urea measurements on the POCT device were not affected by haemolysis or icteric interferences.

It is important to note that the methods compared in this study, as well as in the study conducted by Bargnoux *et al*. (2021), are routine methods rather than reference methods. Consequently, the devices are not being evaluated against a method of exceptional scientific accuracy, but rather against another method that may also possess its own inaccuracies and biases. Although the ABL90 Flex devices have been reported to exhibit a negative bias, the Roche Cobas 8000 c702 displays a positive bias in comparison, and neither is a reference method. Therefore, there is no definitive determination regarding which results are the most accurate. This underscores the importance of training clinicians to recognise the limitations

inherent in these testing methods and to take these into account when interpreting patient results.

A study by Crocker et al. (2014) examined the costs associated with POCT. The findings indicated that POCT can be more expensive than in-house laboratory testing due to a potentially lower number of tests performed per reagent. This could be attributed to reagent expiration or the need for more IQC runs over extended periods, as fewer patient samples are tested. However, POCT can become more cost-effective when a high volume of patient tests is requested. Given the recent challenges faced by Portsmouth Hospitals University NHS Trust, with highly occupied emergency departments, it is likely that the Resus and Majors POCT devices may reach the threshold where they become cost-effective (Taylor, 2022).

6.5 Limitations

Arterial whole blood samples were analysed on ABL90 Flex devices, while peripheral venous serum samples were processed on the Roche Cobas 8000 c702 analyser. This distinction could contribute to slight differences in the results, warranting further assessment. Castro et al. (2024) highlight that PO_2 is generally lower in venous blood, whereas PO_2 is typically higher, leading to a minor pH variation between arterial and venous blood. This pH difference could potentially affect the results. According to Radiometer Medical (2018), there is a minimal level of interference between pH, creatinine and urea measurements on the ABL90 Flex.

Different sample containers were used for the two platforms: lithium heparin syringes for the POCT device and SSTs for the in-house analyser. This variation could also influence the results. Radiometer Medical (2018) indicates that lithium heparin may cause slight interference with urea measurements on the ABL90 Flex, though this occurs at levels below the reportable range. Conversely, a study by Ercan (2020) found that urea and creatinine results obtained from both lithium heparin tubes and SSTs are comparable, showing no significant differences.

A third limitation is the time discrepancy between the analyses. POCT samples are tested immediately after collection, whereas laboratory samples undergo transportation, processing

onto the LIMS system, centrifugation, and eventual analysis. Shepherd (2007) found that a delay of up to 30 hours in centrifuging and separating SST samples has minimal effect on creatinine results when using the Roche enzymatic method. However, Chaudhry *et al*. (2019) report that urea results may be affected if samples are not centrifuged within four hours of collection. Additionally, if samples are left uncapped before analysis, evaporation may occur, leading to an increase in analyte concentration.

Biological variation may also impact the paired patient results as analytes can change drastically throughout the day. Therefore, it was important to ensure that the paired samples were drawn at similar times. For example, urea can be greatly impacted throughout the day by diet and hydration status (Marshall *et al*., 2016).

While Bargnoux *et al*. (2021) suggest that haemolysis and icterus do not affect creatinine and urea results on the ABL90 Flex, it is important to note that these devices lack serum indices testing. Consequently, it cannot be definitively concluded that serum indices had no impact on the results of this study. Lippi *et al*. (2024) report that lipaemia may significantly affect blood gas results, emphasising the importance of serum indices testing. It could be beneficial for a follow-up study to be performed to understand the impact of serum indices on the ABL90 Flex devices in Majors and Resus.

Other pre-analytical factors, such as clotting and air bubbles, may also influence the outcomes. POCT samples are manually loaded onto the analyser and require proper mixing by the operator to prevent air bubbles and ensure that the lithium heparin in the syringe is adequately mixed, avoiding the formation of blood clots (Radiometer Medical, 2018). There is no documentation confirming that these samples were mixed to prevent such pre-analytical errors. This could be a potential area for future research to evaluate the effects of thorough sample mixing prior to analysis and determine whether it significantly influences the results.

Additionally, the ongoing crisis within the NHS represents a potential limitation of this study. Taylor (2022) notes that Portsmouth Hospitals University NHS Trust sometimes experiences full capacity in emergency wards, limiting treatment to only the most urgent cases. This situation could impact the characteristics of the patient population, potentially introducing bias into the study results.

6.6 Implications

The findings of this study demonstrate that the two ABL90 Flex devices meet the manufacturer's claims for urea and creatinine testing, as well as the precision standards established by the Royal College of Pathologists of Australia (2022). Additionally, the observed differences between the two POCT analysers and the Roche Cobas 8000 were deemed not clinically significant and would likely not adversely impact patient care, thus supporting the null hypothesis. This suggests that creatinine and urea testing on the POCT devices could be authorised for clinical use within the Resus and Majors departments of Portsmouth Hospitals University Trust. Such a decision could greatly enhance patient care by enabling quicker result delivery, more rapid clinical decisions, and subsequently faster treatment (Lingervelder *et al*., 2021). This could also benefit the NHS by alleviating the strain of fully occupied wards, as noted by Taylor (2022), potentially reducing inpatient stays.

Implementing these tests may also alleviate the financial burden on the NHS. Studies have shown that these tests can detect AKI before significant damage occurs (Hall *et al*., 2018), potentially reducing the prevalence of complications and the need for costly further treatment.

This study highlights the positive impact that POCT can have on both patient care and the financial sustainability of the NHS, suggesting that expanding the range of tests available through POCT could be highly beneficial in the future. For example, heart disease remains a significant concern in healthcare, with approximately 50% of diagnosed and admitted patients being readmitted within one year. Early diagnosis through POCT could facilitate quicker treatment, reduce complications, and improve patient outcomes (Goble and Rocafort, 2016). A study has already been conducted to validate the use of the ABL90 Flex for Nt-ProBNP testing, which is utilised to diagnose and assess the severity of heart failure. The study reported no significant difference between the ABL90 Flex and a laboratory analyser, concluding that the test could be approved for clinical use (Lepoutre *et al*., 2013). This underscores the promising potential for the future expansion of POCT testing.

However, the success of such expansions depends significantly on clinical education and continued engagement with laboratory quality processes. Education on the impact of pre-analytical factors is crucial, as improperly maintained machines can pose serious risks. The laboratory will continue to provide comprehensive training, and the EQA programme will

remain in place to ensure the most suitable POCT methods are employed. This will help maintain accuracy, safety, and clinical effectiveness in POCT, thereby contributing to the ongoing improvement of patient care.

7.0 Conclusion

The primary findings of this study indicate that the two POCT devices, the ABL90 Flex ‘Majors’ and ‘Resus’, demonstrate acceptable precision for creatinine and urea testing, as per the standards set by the Royal College of Pathologists of Australia (2022). Additionally, these devices perform well when compared to other ABL90 Flex devices involved in the same WEQAS scheme, as well as each other, further confirming their reliability. Although a slight difference was observed between the POCT devices and the Roche Cobas 8000 c702, this variation is unlikely to have a clinically significant impact. These findings support the study's null hypothesis and suggest that adding these tests to the POCT profile a viable option and wet live after this verification took place.

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9.0 References

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10.0 Appendices

Appendix 1: A table to show the internal quality control intra assay results for urea and creatinine on the Roche Cobas 8000 c702.

Intra assay	UREA (mmol/L)		CREA (umol/L)	
	Tpath 1	Tpath 3	Tpath 1	Tpath 3
15.01.24	2.8	21.8	61.5	527.0
	2.8	21.7	61.5	525.6
	2.8	21.8	62.5	526.3
	2.8	21.9	61.1	527.7
	2.7	21.7	61.5	527.4
	2.8	21.6	62.5	522.5
	2.8	21.9	61.1	527.4
	2.9	21.7	62.5	525.0
	2.9	21.9	61.8	527.4
	2.9	22.0	62.2	527.7
	2.8	21.1	62.5	517.3
	2.8	21.2	62.9	532.6
	2.8	21.1	61.5	526.0
	2.8	20.9	60.8	532.6
	2.8	21.2	61.8	527.7
	2.8	21.3	61.1	531.2
	2.8	21.2	62.2	528.1
	2.8	21.3	62.2	525.3
	2.7	21.3	62.9	532.6
	2.8	21.3	63.2	528.8
Mean	2.805	21.495	61.965	527.31
SD	0.051042	0.33635	0.692269	3.560588
CV (%)	1.819671	1.564784	1.117194	0.675236
Range	0.2	1.1	2.4	15.3

Appendix 2: A table to show the internal quality control inter assay results for urea and creatinine on the Roche Cobas 8000 c702.

Inter assay	UREA (mmol/L)		CREA (umol/L)	
	Tpath 1	Tpath 3	Tpath 1	Tpath 3
15.01.24	2.8	21.6	60.0	511.0
	2.9	21.7	61.3	523.1
	2.8	21.6	61.0	514.7
16.01.24	2.7	21.3	60.6	522.1
	2.9	21.9	59.3	510.0
	2.8	21.6	60.0	515.4
17.01.24	2.8	21.3	61.0	515.0
	2.8	21.5	60.0	519.0
	2.9	22.2	61.3	516.4
19.01.24	2.8	21.6	61.6	519.8
	2.7	21.0	60.6	516.7
	2.7	20.6	61.6	525.5
20.01.24	2.9	21.8	62.6	530.2
	2.8	21.2	60.8	518.5
	2.9	21.4	61.2	520.1
21.01.24	2.8	21.6	62.1	512.4
	2.8	21.1	61.8	516.8
22.01.21	2.8	21.5	60.4	522.3
	2.9	21.9	61.3	520.5
	2.7	20.3	60.6	516.6
Mean	2.81	21.435	60.955	518.305
SD	0.071818	0.443995	0.800312	4.911584
CV (%)	2.555818	2.071355	1.312956	0.947624
Range	0.2	1.9	2.6	15.5

Appendix 3: A table to show the internal quality control intra assay results for urea and creatinine on the 'Resus' ABL90 Flex.

Intra-assay	Urea			Crea		
Date	A - S9230	B - S9240	C - S9250	A - S9230	B - S9240	C - S9250
24.01.24	-0.1	15.8	5.7	2	64	424
	-0.1	16	5.9	2	64	432
	-0.1	15.9	5.9	2	65	430
	-0.1	15.5	5.9	2	64	431
	-0.1	16.1	5.9	2	67	431
	-0.1	16.1	5.8	2	66	432
	-0.1	16	5.8	2	65	431
	-0.1	15.8	5.9	2	64	431
	-0.1	16.3	5.9	2	65	430
	-0.1	16.2	5.9	2	67	432
	-0.1	16.2	5.9	2	66	438
	-0.1	16.2	5.8	2	66	432
	-0.1	16.2	5.8	2	66	431
	-0.1	16.1	5.8	2	65	433
	-0.1	16	5.8	2	65	432
	-0.1	15.7	5.7	2	64	427
	-0.1	15.9	5.9	2	67	435
	-0.1	15.8	5.8	2	68	436
	-0.1	17	5.9	2	68	433
	-0.1	16.8	5.9	2	68	437
Mean	-0.1	16.08	5.845	2	65.7	431.9
SD	N/A	0.345802	0.068633	0	1.41793	3.160613
CV (%)	N/A	2.150509	1.174222	0	2.158189	0.731793
Range	0	1.3	0.2	0	4	14

Appendix 4: A table to show the internal quality control inter assay results for urea and creatinine on the 'Resus' ABL90 Flex.

Inter-assay	Urea			Crea		
Date	A - S9230	B - S9240	C - S9250	A - S9230	B - S9240	C - S9250
18.01.24	-0.10	16.10	5.4	2.00	70.00	413
	-0.10	16.20	5.5	2.00	65.00	409
	-0.10	16.20	5.6	2.00	69.00	404
19.01.24	-0.10	15.60	5.4	2.00	67.00	409
	-0.10	15.30	5.7	2.00	65.00	438
	-0.10	15.10	5.4	2.00	67.00	420
20.01.24	-0.10	15.30	5.4	2.00	63.00	417
	-0.10	15.10	5.4	2.00	65.00	395
	-0.10	15.20	5.4	2.00	66.00	422
21.01.24	-0.10	15.80	5.4	2.00	64.00	410
	-0.10	15.30	5.4	2.00	67.00	423
	-0.10	15.80	6.2	2.00	64.00	423
22.01.24	-0.10	14.80	5.4	2.00	68.00	408
	-0.10	14.30	5.6	1.00	65.00	425
	-0.10	15.40	5.5	2.00	63.00	403
23.01.24	-0.10	15.80	5.3	2.00	64.00	414
	-0.10	15.70	5.8	2.00	68.00	447
	-0.10	16.10	5.7	2.00	62.00	420
24.01.24	-0.10	16.20	5.8	1.00	64.00	427
	-0.10	15.90	5.5	2.00	65.00	441
Mean	-0.1	15.56	5.54	1.9	65.55	418.4
SD	N/A	0.516466	0.213739	0.307794	2.139233	13.15655
CV (%)	N/A	3.319188	3.858098	16.19966	3.263513	3.14449
Range	0	1.9	0.9	1	8	52

Appendix 5: A table to show the internal quality control intra assay results for urea and creatinine on the 'Majors' ABL90 Flex.

Intra-assay	Urea			Crea		
Date	A - S9230	B - S9240	C - S9250	A - S9230	B - S9240	C - S9250
24.01.24	-0.10	16.9	6	2	65	410
	-0.10	17	5.9	2	65	407
	-0.10	17	5.9	2	64	415
	-0.10	16.9	5.9	2	63	415
	-0.10	16.1	5.9	2	66	415
	-0.10	16.5	5.9	2	66	417
	-0.10	16.6	5.9	2	66	416
	-0.10	16.6	5.9	2	65	417
	-0.10	16.6	5.9	2	65	420
	-0.10	16.6	5.9	2	65	421
	-0.10	16.5	5.4	2	65	423
	-0.10	16.5	5.9	2	65	424
	-0.10	16.5	5.9	2	65	423
	-0.10	16.3	5.9	2	64	424
	-0.10	16.2	5.9	2	62	429
	-0.10	16.5	5.9	2	64	424
	-0.10	16.4	5.9	2	63	425
	-0.10	16.7	6	2	65	425
	-0.10	16.7	6	2	64	427
	-0.10	16.6	6	2	64	430
Mean	-0.1	16.585	5.895	2	64.55	420.35
SD	N/A	0.241214	0.123438	0	1.050063	6.166761
CV (%)	N/A	1.454411	2.093937	0	1.626743	1.467054
Range	0	0.9	0.1	0	3	23

Appendix 6: Appendix 5: A table to show the internal quality control inter assay results for urea and creatinine on the 'Majors' ABL90 Flex.

Inter-assay	Urea			Crea		
Date	A - S9230	B - S9240	C - S9250	A - S9230	B - S9240	C - S9250
18.01.24	-0.10	15.70	5.5	2.00	64.00	420
	-0.10	15.70	5.6	2.00	67.00	446
	-0.10	16.30	5.4	2.00	66.00	437
19.01.24	-0.10	16.00	5.5	2.00	67.00	452
	-0.10	15.90	5.4	2.00	66.00	447
	-0.10	15.50	5.7	2.00	69.00	451
20.01.24	-0.10	16.10	5.4	2.00	64.00	422
	-0.10	15.70	5.6	2.00	67.00	428
	-0.10	15.40	5.7	2.00	69.00	447
21.01.24	-0.10	15.50	5.7	2.00	69.00	443
	-0.10	16.30	5.4	2.00	65.00	431
	-0.10	16.10	5.6	2.00	65.00	423
22.01.24	-0.10	15.50	5.5	2.00	62.00	443
	-0.10	16.00	5.6	2.00	70.00	453
	-0.10	16.20	5.7	2.00	65.00	419
23.01.24	-0.10	16.20	5.4	2.00	65.00	425
	-0.10	15.80	5.7	2.00	68.00	444
	-0.10	16.50	5.3	2.00	68.00	448
24.01.24	-0.10	15.80	5.7	2.00	66.00	442
	-0.10	16.30	5.3	2.00	64.00	442
Mean	-0.1	15.925	5.535	2	66.3	438.15
SD	N/A	0.322613	0.142441	0	2.105132	11.51326
CV (%)	N/A	2.025825	2.573462	0	3.175161	2.627699
Range	0	1.1	0.4	0	6	29