DIAGNOSTICS

Total Cost of Ownership (TCO): An evidence-based approach to compare laboratory equipment

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SUMMARY

Clinical laboratories across the globe operate in a rapidly changing environment, with new regulations, increasing test volumes, and growing cost pressures. As diagnostics manufacturers develop and release new generations of analyzers and analytic platforms, laboratory managers must make objective technical decisions regarding the best laboratory instrumentation to meet their needs.

The total cost of ownership (TCO) methodology provides lab managers with a structured approach to analyzing all direct and indirect costs associated with a specific instrument, allowing for comparative, evidence-based decision making that controls laboratory costs while still ensuring high-quality test results.

In this study, four independent laboratories ran clinical chemistry and immunoassay test panels for 30 analytes on an identical set of patient specimens and controls, using standardized protocols on five different analytic platforms from Abbott (Alinity ci-series and ARCHITECT *ci*8200), Beckman Coulter (AU2700/DxI 800), Roche (cobas 8000), and Siemens (ADVIA 1800/ Centaur XP). Three key operational efficiency areas that contribute to TCO are highlighted in this paper: maintenance time, processing time, and utility consumption. In addition, the linearity interval of each analyzer was determined on control samples of four analytes.

Compared to other analytical systems, Abbott's Alinity ci-series was superior in all three performance characteristics, suggesting a lower TCO. The Alinity ci-series and ARCHITECT *ci*8200 systems also produced consistent results in linearity of control sample measurements across the two platforms.

INTRODUCTION

In an effort to maintain a high level of laboratory operational efficiency, laboratorians often evaluate their current instrumentation, new generations of analyzers, and other resources, including staff and time constraints, to best manage lab key performance indicators (KPIs). Often, lab managers will focus on the cost of reagents or staff, without considering the much larger array of factors that contribute to the TCO of their lab equipment. A TCO analysis takes into account the various direct and indirect variables associated with running an analytic instrument to produce consistently accurate results. Whereas the cost per test or the cost per reported result may only consider the cost of reagents and the equipment itself, the TCO approach incorporates costs associated with each analytical step, as well as the likelihood of errors; the need for repeat analysis and reruns; equipment maintenance; utility costs; and turnaround time (TAT), the time needed to perform the test.

In this study, a TCO analysis was conducted, comparing Abbott's new integrated analytical platform, Alinity ci-series, to its previous platform, ARCHITECT *ci*8200, and to other analytical platforms from Beckman Coulter, Roche, and Siemens.

METHODS

Comparator Analytic Platforms

Four independent laboratories were recruited to participate in this study, matched for laboratory size, menu offerings, analyzer configurations, and annual volumes. Each site ran an identical set of patient specimens and controls, using standardized protocols on five different analytic platforms from Abbott, Beckman Coulter, Roche, and Siemens (Table 1).

Table 1. Analytic platforms included in the study

Supplier	Analyzers
Abbott (Paris, France)	Alinity ci-series
Abbott (Paris, France)	ARCHITECT *ci*8200
Beckman Coulter (Bordeaux, France)	AU2700/DxI 800
Roche (Bayonne, France)	cobas 8000 • ISE • c701 • e602
Siemens (Medellin, Colombia)	ADVIA 1800/Centaur XP

Samples and Test Panels

Samples run on the five analytic platforms at each of the test sites were prepared by a large private laboratory in France. Each identical set of 160 patient samples was prepared and aliquoted into randomly selected primary tubes for clinical chemistry, immunoassay, and mixed test panels. All analytes and test panels included in the study and the number of tubes included in each test panel are listed in the Appendix, Tables 4 and 5.

A separate STAT test protocol was developed to simulate the mix of routine and STAT tests run by a laboratory during normal operations. All tubes for routine test panels (n = 134 tubes, n = 1,270 tests) were placed on the instrument and started simultaneously, in random order. To simulate the disruption caused by STAT samples, STAT tubes (n = 32 tubes, 180 tests) were added per the schedule presented in the Appendix, Table 6. STAT requests were introduced during routine test panels at the same time intervals at each test site.

TCO Measures

Three key operational efficiency factors that contribute to TCO were monitored for the five analytic platforms at each of the four test sites.

1. **Maintenance time:** Machine downtime was defined as the time required to perform daily, weekly, and monthly maintenance on the analyzer, as outlined in the operations manuals (such as cleaning probes, mixers, filters, etc.), during which the analyzer is unavailable. Human time was calculated as the time during which a technologist interacted with the analyzer to perform maintenance activities.
2. **Processing time:** Peak performance time was calculated as the time required to process 172 routine and STAT tubes (160 patient samples and 12 control samples), from the point the tubes were placed on the analyzer to retrieval of the last result from the laboratory information system (LIS). The average STAT tube processing time was also determined.
3. **Utility consumption:** During sample processing, consumption of electricity by the platform was measured in British thermal units (BTUs).

Linearity Control Measurements

Linear control samples from the VALIDATE Chem 4 kit (LGC Maine Standards), comprising six tubes with increasing concentrations of aspartate transaminase (AST), alanine transaminase (ALT), alkaline phosphatase (AlkP), and amylase, were analyzed in duplicate for a total of 12 control tubes. Control tubes were loaded randomly onto the analyzers. Linearity intervals were compared across the analytic platforms for each analyte.

Data Analysis

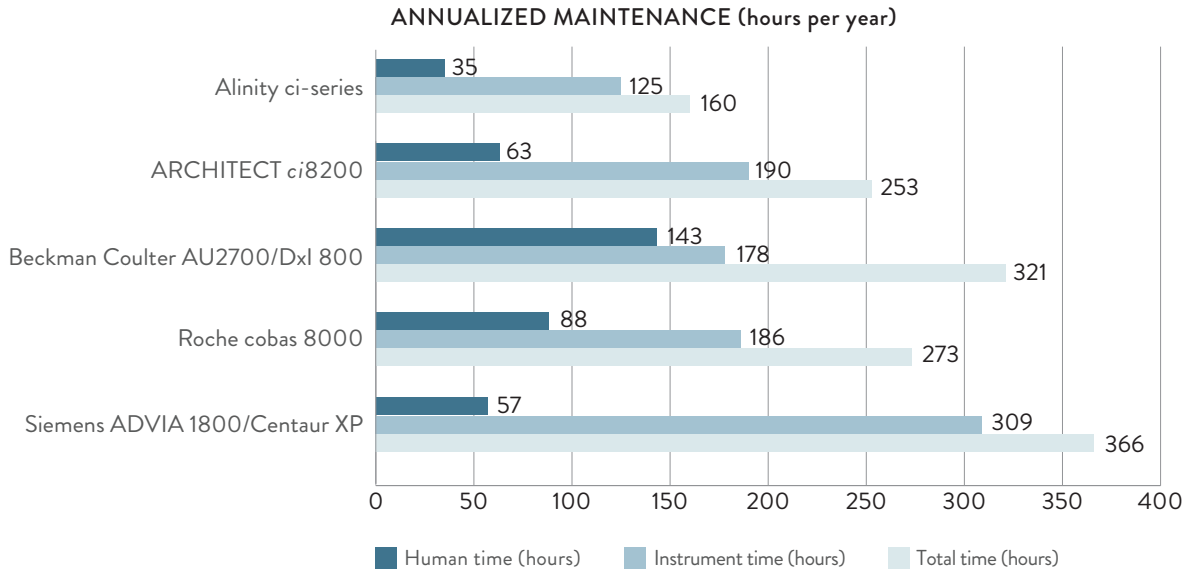
TCO measures and linearity control measurements were averaged from the four test sites, and average values were compared across the five analytic platforms, using descriptive statistics.

RESULTS

Maintenance Time

Figure 1 shows the annualized maintenance time for each analytic platform. The Alinity ci-series outperformed all other analytic platforms in terms of both analyzer downtime for maintenance and the number of hours staff members were engaged in maintenance activities. The Alinity ci-series required 41%, 50%, 56%, and 37% less annualized maintenance time than the Roche, Beckman Coulter, Siemens, and Abbott ARCHITECT platforms, respectively.

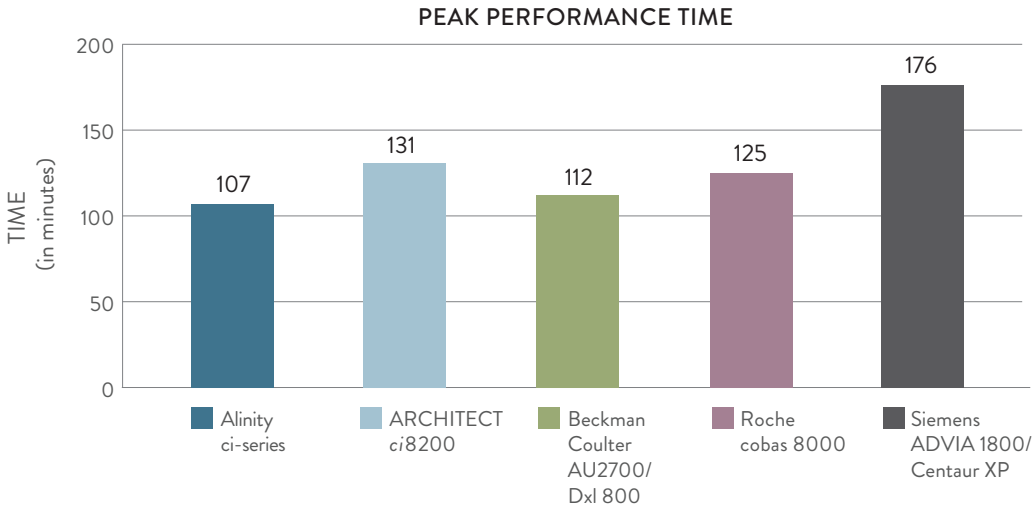
Figure 1. Maintenance time for analytic platforms



Processing Time

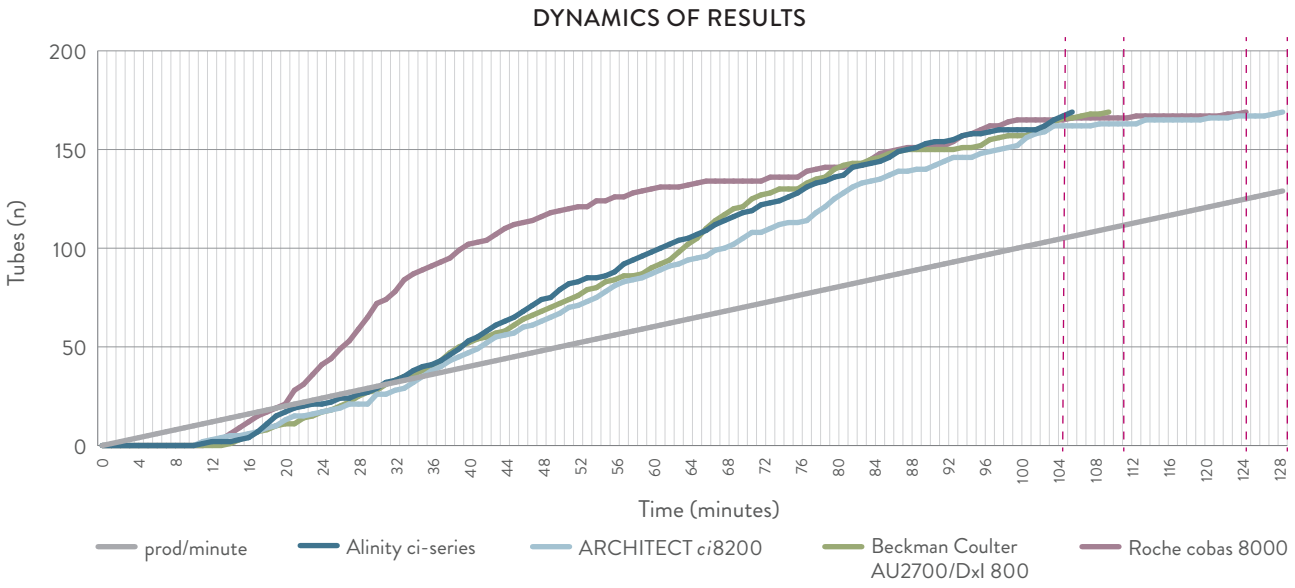
Peak performance (throughput) of each analytic platform, measured as the time to analyze 172 specimen tubes, is shown in Figure 2. The Alinity ci-series throughput 172 tubes in 107 minutes, which was 4.5%, 14%, 39%, and 18% faster than the Beckman Coulter, Roche, Siemens, and Abbott ARCHITECT platforms, respectively.

Figure 2. Peak performance of analytic platforms



A comparison of processing time dynamics, Figure 3 below shows that the Alinity ci-series, ARCHITECT, and Beckman Coulter AU2700/DxI 800 analytic platforms have a uniform linear result curve, reflecting consistent tube processing timing. As in Figure 2, the Alinity ci-series had the fastest peak performance time (dashed lines), while the Roche cobas 8000 platform had the fastest processing speed, up to the first 130 samples, which then plateaued in a system "saturation" phenomenon. The Siemens platform (ADVIA 1800/Centaur XP) was not included in this analysis, due to technical limitations of the labs' LIS in accessing individual tube processing times.

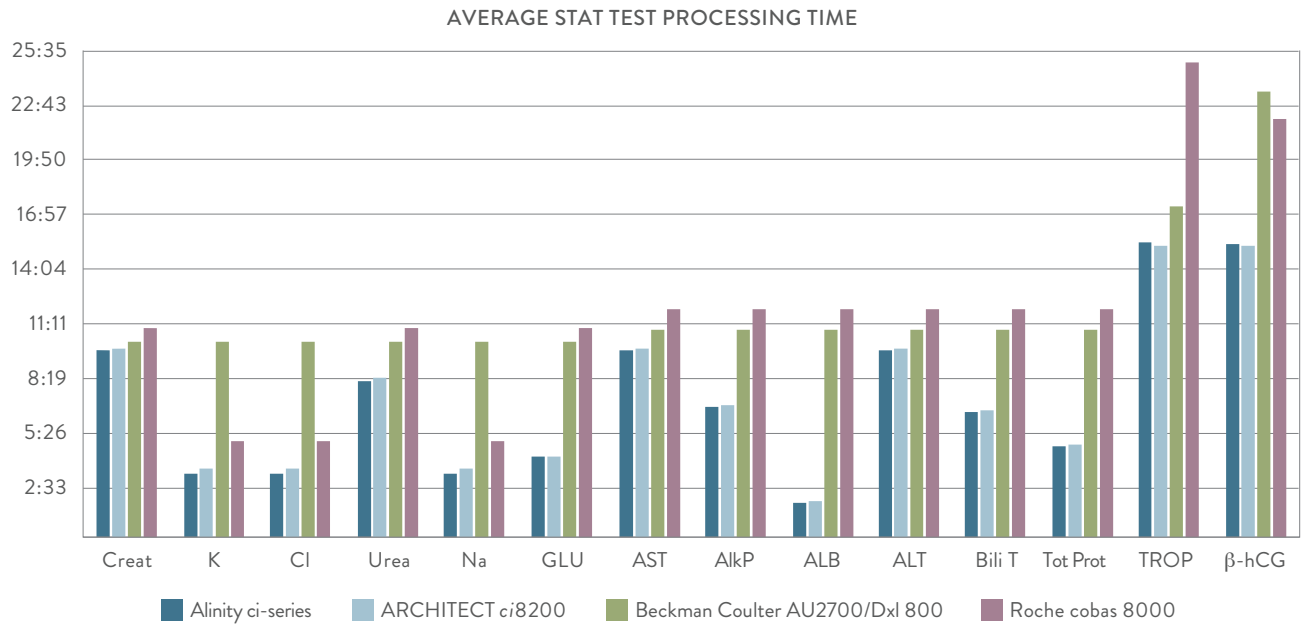
Figure 3. Dynamic tube processing by each analytic platform



Because STAT tests are commonly run in the clinical setting, a measurement was taken of the processing time of STAT test tubes that were introduced into the routine test panels at specific times (Appendix, Table 6). Figure 4 shows the average STAT test times for the Alinity ci-series, ARCHITECT *ci*8200, Beckman Coulter AU2700/DxI 800 analyzers, and Roche cobas 8000. Note that standard Roche test kits were used for troponin-T and β-hCG tests on the cobas 8000 platform (versus STAT test kits with a shortened protocol). Again, the Siemens ADVIA 1800/Centaur XP platform was not included in this analysis, due to LIS limitations and the inability to assess individual tube processing times.

For all STAT tests, the Alinity ci-series and ARCHITECT *ci*8200 platforms had lower processing times compared to the Beckman Coulter AU2700/DxI 800 and Roche cobas 8000 platforms; creatinine, AST, and ALT had similar STAT test processing times across the four platforms.

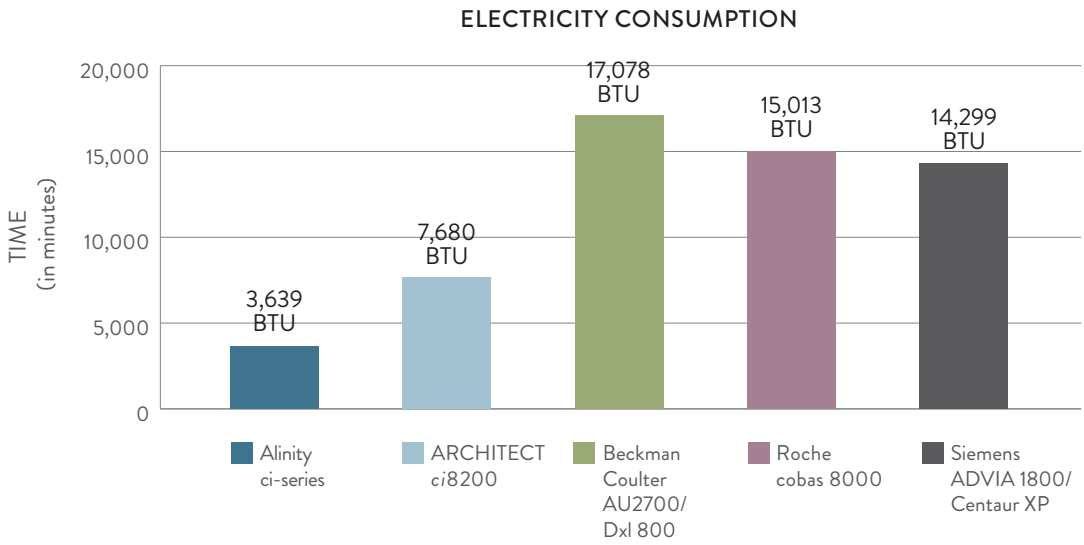
Figure 4. Average STAT time per test comparison for each platform



Utility Consumption

Electricity consumption was also examined for each of the five analytic platforms in the study, using data from the analyzers' manuals. Abbott's Alinity ci-series platform consumed 75%, 76%, 79%, and 53% less electricity than the Roche, Beckman Coulter, Siemens, and Abbott ARCHITECT platforms, respectively (Figure 5).

Figure 5. Electricity consumption by each analytic platform



Linearity of Control Sample Measurements

We also evaluated the linearity interval of each analytic platform as a key operational efficiency factor that contributes to TCO (Table 2). Of note, the Beckman Coulter AU2700/DxI 800 analyzer was unable to measure AlkP in the lowest-concentration control sample (C1), and the Siemens ADVIA 1800/Centaur XP was unable to measure amylase in the highest-concentration control sample (C6). Low levels of analytes (out of linearity interval) cannot be precisely measured and require reruns after dilution, which can lead to loss of quality. High analyte levels in the sample (out of linearity interval) require additional reruns, as well. Reruns increase TAT and direct costs for analysis and, at least, double the cost of analyzing the sample.

Table 2. Linearity of control sample measurements

Analyte	Platform	C1	C2	C3	C4	C5	C6
ALT	Abbott Alinity ci-series	9.2	220	433	644	852	3,271
	Abbott ARCHITECT *ci*8200	9.5	221	430	644	854	3,561
	Beckman Coulter AU2700/DxI 800	8.5	205	404	637	859	3,677
	Roche cobas 8000	7.0	198	390	578	788	3,345
	Siemens ADVIA 1800/Centaur XP	9.5	223	434	639	849	3,270
AST	Abbott Alinity ci-series	6.4	213	416	618	818	3,634
	Abbott ARCHITECT *ci*8200	6.8	209	411	613	813	3,613
	Beckman Coulter AU2700/DxI 800	7.0	216	422	621	844	4,017
	Roche cobas 8000	4.5	210	411	606	814	3,643
	Siemens ADVIA 1800/Centaur XP	9.0	217	425	628	838	3,551
AlkP	Abbott Alinity ci-series	5.9	518	1,014	1,506	1,978	3,972
	Abbott ARCHITECT *ci*8200	5.8	542	1,060	1,573	2,066	4,188
	Beckman Coulter AU2700/DxI 800	**<5**	582	1,141	1,781	2,375	4,808
	Roche cobas 8000	4.0	410	792	1,161	1,564	3,091
	Siemens ADVIA 1800/Centaur XP	3.0	429	803	1,167	1,555	3,130
Amyl	Abbott Alinity ci-series	6.3	746	1,478	2,197	2,904	6,119
	Abbott ARCHITECT *ci*8200	6.5	762	1,505	2,251	2,967	6,258
	Beckman Coulter AU2700/DxI 800	6.0	647	1,305	2,019	2,688	5,571
	Roche cobas 8000	5.0	600	1,167	1,767	2,413	4,983
	Siemens ADVIA 1800/Centaur XP	6.0	637	1,193	1,722	2,310	**N.R.**

C = concentration of the control samples in U/L, with increasing concentration of analytes from C1 through C6

ALT = alanine transaminase; AST = aspartate transaminase; AlkP = alkaline phosphatase; Amyl = amylase; N.R. = no result

DISCUSSION

This study demonstrated that, compared to other analytical systems, Abbott's Alinity ci-series was superior in three key operational efficiency areas that contribute to TCO (Table 3).

Table 3. Summary of superiority in TCO factors for the Alinity ci analytic platform vs. other platforms

	ARCHITECT ci8200	Beckman Coulter AU2700/DxI 800	Roche cobas 8000	Siemens ADVIA 1800/Centaur XP
Alinity ci-series Maintenance Time	37% less	50% less	41% less	56% less
Alinity ci-series Processing Time	18% less	4.5% less	14% less	39% less
Alinity ci-series Electricity Consumption	53% less	79% less	76% less	75% less

The Abbott analyzers (Alinity ci-series and ARCHITECT *ci*8200) were also superior to the Roche cobas 8000 and the Beckman Coulter AU2700/DxI 800, in terms of STAT sample processing time for all analytes, with a consistent rate of tube processing. Again, the Siemens ADVIA 1800/Centaur XP platform was not included in the processing time analysis, as we were unable to assess individual tube processing times, due to LIS limitations within the laboratory.

With regard to the linearity of control sample measurements, the Alinity ci-series and ARCHITECT *ci*8200 systems produced similar results, but variability of up to 50% was noted across the five analytic platforms. Sensitive test systems with expanded linearity intervals are thought to be more efficient, as a greater proportion of samples have results within the range of detection. High analyte levels in the sample that are outside the linearity interval require dilution and reruns that increase TAT, reducing efficiency and increasing the TCO. Samples with low analyte concentrations outside the linearity interval cannot be precisely measured, also reducing laboratory efficiency and increasing TCO. Because of limitations in the study's informatics systems, it was not possible to estimate the rerun ratio due to dilution of samples outside the linearity interval for each analytic platform. This factor is an important contributor to TCO and will be investigated in future studies.

Other components of TCO, including time needed for parts replacement, calibration, QC, reagent loading, water consumption, and ease of use, were assessed during the study, and these results will be discussed in a future report. To accurately compare TCO across analytic platforms and calculate the cost of assay performance, laboratory managers may want to consider the larger set of factors that contributes to TCO.

CONCLUSIONS

This study highlights the importance of adopting a TCO approach to more accurately assess the costs associated with diagnostic instrumentation in the clinical laboratory. It used a robust prospective design to compare key performance characteristics across five different platforms, running an identical set of samples using standard protocols in four independent laboratories. This is the first study to directly compare maintenance time, processing time, and electricity consumption of the Alinity ci-series to other commonly used analytical systems.

The Alinity ci-series from Abbott Diagnostics achieved the highest operational efficiency among the five platforms tested, suggesting a lower TCO.

APPENDIX

Abbreviations

ALB.....Albumin
AlkP.....Alkaline Phosphatase
ALT.....Alanine Aminotransferase
Amyl.....Amylase
AST.....Aspartate Aminotransferase
β-hCG.....Beta-Human Chorionic Gonadotropin
Bili T.....Total Bilirubin
BTU.....British Thermal Unit
Ca.....Calcium
CEA.....Carcinoembryonic Antigen
Chol.....Cholesterol
Cl.....Chloride
CO_2.....Carbon Dioxide
Creat.....Creatinine
GLU.....Glucose
HDL.....High-Density Lipoprotein
hs.....High Sensitivity
hsTnl.....High Sensitive Troponin I
K.....Potassium
LIS.....Laboratory Information System
Na.....Sodium
N.R.....No Result
Phos.....Phosphorus
TAT.....Turnaround Time
TCO.....Total Cost of Ownership
Tot Prot.....Total Protein
Trig.....Triglyceride
TROP.....Troponin
TSH.....Thyroid-Stimulating Hormone
Vanco.....Vancomycin

Table 4. Tested analytes in the study

Clinical Chemistry Tests	Immunoassays
Albumin	β-hCG
AlkP	Ferritin
ALT	Troponin I
Amylase	CEA
AST	TSH
Bili T	
Calcium	
Chloride	
Cholesterol	
CO_2	
Creatinine	
Digoxin	
Ethanol	

Clinical Chemistry Tests	Immunoassays
Glucose	
HDL	
Magnesium	
Phosphorus	
Potassium	
Sodium	
Total Protein	
Transferrin	
Triglyceride	
Urea	
Uric Acid	
Vancomycin	

Table 5. Test panels included in the protocol

Panel	Number of Tubes
Albumin, AlkP, ALT, AST, Bili T, Ca, Glucose, Cl, CO_2, Creat, K, Na, Urea, Total Protein	4
Albumin, AlkP, ALT, AST, Bili T, Magnesium, Total Protein	2
Albumin, AlkP, AST, Bili T, Ca, Glucose, Magnesium, Phos, Cl, CO_2, Creat, K, Na, Urea	2
Albumin, AlkP, AST, Bili T, Ca, Magnesium, Phos, Glucose, Cl, CO_2, Creat, K, Na, Urea	2
Albumin, AlkP, AST, Bili T, Ca, Magnesium, Phos, Glucose, Cl, CO_2, Creat, K, Na, Urea	2
Albumin, AlkP, AST, Bili T, Ferritin, Magnesium, Phos	2
Albumin, AlkP, Bili T, AST, Ca, Magnesium, Phos, Glucose, Cl, CO_2, Creat, K, Na, Urea	2
Albumin, Ca, Chol, Glucose, Phos, Cl, CO_2, Creat, K, Na, Urea, Trig, Uric Acid	2
Albumin, Ca, Ferritin, Glucose, Chol, HDL, Trig, Phos, Cl, CO_2, Creat, K, Na, Urea, Uric Acid	2
Amylase, Ca, Glucose, Cl, CO_2, Creat, K, Na, Urea	2
Amylase, Magnesium	2
Amylase, Transferrin, Magnesium	2
AST, Albumin, AlkP, ALT, Bili T, Total Protein	2
AST, Amylase, Ethanol, Albumin, AlkP, ALT, Bili T, Total Protein	2
AST, Ca, Chol, Glucose, Albumin, AlkP, ALT, Bili T, Cl, CO_2, Creat, K, Na, Urea, Total Protein, Trig	6
AST, Ca, Digoxin, Glucose, Albumin, AlkP, ALT, Bili T, Cl, CO_2, Creat, K, Na, Urea, Total Protein	2
AST, Ca, Ferritin, Glucose, Albumin, AlkP, ALT, Bili T, Cl, CO_2, Creat, K, Na, Urea, Total Protein, TSH	6
AST, Ca, Glucose, Albumin, AlkP, ALT, Bili T, CEA, Cl, CO_2, Creat, K, Na, Urea, Total Protein	2
AST, Ca, Glucose, Albumin, AlkP, ALT, Bili T, Cl, CO_2, Creat, K, Na, Urea, Total Protein, TSH	2
AST, Ca, Glucose, Albumin, AlkP, ALT, Bili T, Cl, CO_2, Creat, K, Na, Urea, Total Protein, TSH, Ferritin	2
AST, Ca, Glucose, Chol, HDL, Trig, Albumin, AlkP, ALT, Bili T, CEA, Cl, CO_2, Creat, K, Na, Urea, Total Protein, Troponin I	2
AST, Ca, Glucose, Chol, HDL, Trig, Albumin, AlkP, ALT, Bili T, Cl, CO_2, Creat, K, Na, Urea, Total Protein, Ferritin, Troponin I	2
AST, Ca, Vanco, Glucose, Albumin, AlkP, ALT, Bili T, Cl, CO_2, Creat, K, Na, Urea, Total Protein	4
AST, Chol, Albumin, AlkP, ALT, Bili T, Total Protein, Trig, Uric Acid	2
AST, Chol, Creat, Trig	2
AST, Creat, Chol, HDL, Trig	2
AST, Creat, Chol, Trig	2
AST, Ferritin, Magnesium, Albumin, AlkP, ALT, Bili T, Total Protein, TSH	2
Ca, Chol, Glucose, CEA, Cl, CO_2, Creat, K, Na, Urea, Trig	2
Ca, Chol, Glucose, Cl, CO_2, Creat, K, Na, Urea, Trig, Troponin I	2
Ca, Digoxin, Glucose, Cl, CO_2, Creat, K, Na, Urea	2
Ca, Ferritin, Glucose, Cl, CO_2, Creat, K, Na, Urea	2
Ca, Ferritin, Glucose, Cl, CO_2, Creat, K, Na, Urea	2

Table 5. Test panels included in the protocol (continued)

Panel	Number of Tubes
Ca, Ferritin, Glucose, Cl, CO_2, Creat, K, Na, Urea, TSH	2
Ca, Glucose, CEA, Cl, CO_2, Creat, K, Na, Urea	2
Ca, Glucose, CEA, Cl, CO_2, Creat, K, Na, Urea	4
Ca, Glucose, Chol, HDL, Trig, Cl, CO_2, Creat, K, Na, Urea	2
Ca, Glucose, Cl, CO_2, Creat, K, Na, Urea	6
Ca, Glucose, Cl, CO_2, Creat, K, Na, Urea	6
Ca, Glucose, Cl, CO_2, Creat, K, Na, Urea, Troponin I	2
Ca, Transferrin, Glucose, Cl, CO_2, Creat, K, Na, Urea	2
Ca, Transferrin, Glucose, Cl, CO_2, Creat, K, Na, Urea	2
Ca, Vanco, Glucose, Cl, CO_2, Creat, K, Na, Urea	2
CEA	2
CEA, TSH	2
Chol, HDL, Trig	2
Chol, Trig	2
Digoxin	2
Ferritin, TSH	2
Ferritin, TSH, Troponin I	2
TSH	6

Table 6. STAT test panels and timing

STAT Test Panel	Time From Start (min)
STAT Troponin I	5
STAT Troponin I	5
STAT Transferrin	10
STAT Amylase, Ca, Glucose, Cl, CO_2, Creat, K, Na, Urea	12
STAT Troponin I	15
STAT AST, Ca, Magnesium, Phos, Digoxin, Glucose, Albumin, AlkP, ALT, Bili T, Cl, CO_2, Creat, K, Na, Urea, Total Protein, Troponin I	20
STAT Ca, Glucose, Cl, CO_2, Creat, K, Na, Urea, Troponin I	25
STAT AST, Ca, Ethanol, Glucose, Albumin, AlkP, ALT, Bili T, Cl, CO_2, Creat, K, Na, Urea, Total Protein, Troponin I	25
STAT β-hCG	30
STAT β-hCG	35
STAT Troponin I	40
STAT Troponin I	40
STAT Ca, Glucose, Cl, CO_2, Creat, K, Na, Urea, Troponin I	45
STAT β-hCG	50
STAT CA, Glucose, Cl, CO_2, Creat, K, Na, Urea, Troponin I	55
STAT Amylase, Ca, Glucose, Cl, CO_2, Creat, K, Na, Urea	60
STAT Troponin I	65
STAT Troponin I	65
STAT Transferrin	70
STAT Amylase, Ca, Glucose, Cl, CO_2, Creat, K, Na, Urea	72
STAT Troponin I	75
STAT AST, Ca, Magnesium, Phos, Digoxin, Glucose, Albumin, AlkP, ALT, Bili T, Cl, CO_2, Creat, K, Na, Urea, Total Protein, Troponin I	80
STAT Ca, Glucose, Cl, CO_2, Creat, K, Na, Urea, Troponin I	85
STAT AST, Ca, Ethanol, Glucose, Albumin, AlkP, ALT, Bili T, Cl, CO_2, Creat, K, Na, Urea, Total Protein, Troponin I	85
STAT β-hCG	90
STATβ-hCG	95
STAT Troponin I	100
STAT Troponin I	100
STAT Ca, Glucose, Cl, CO_2, Creat, K, Na, Urea, Troponin I	105
STAT β-hCG	110
STAT Ca, Glucose, Cl, CO_2, Creat, K, Na, Urea, Troponin I	115
STAT Amylase, Ca, Glucose, Cl, CO_2, Creat, K, Na, Urea	120

Figure 6. Results of linearity control measurement comparison curves – average of two dimensions

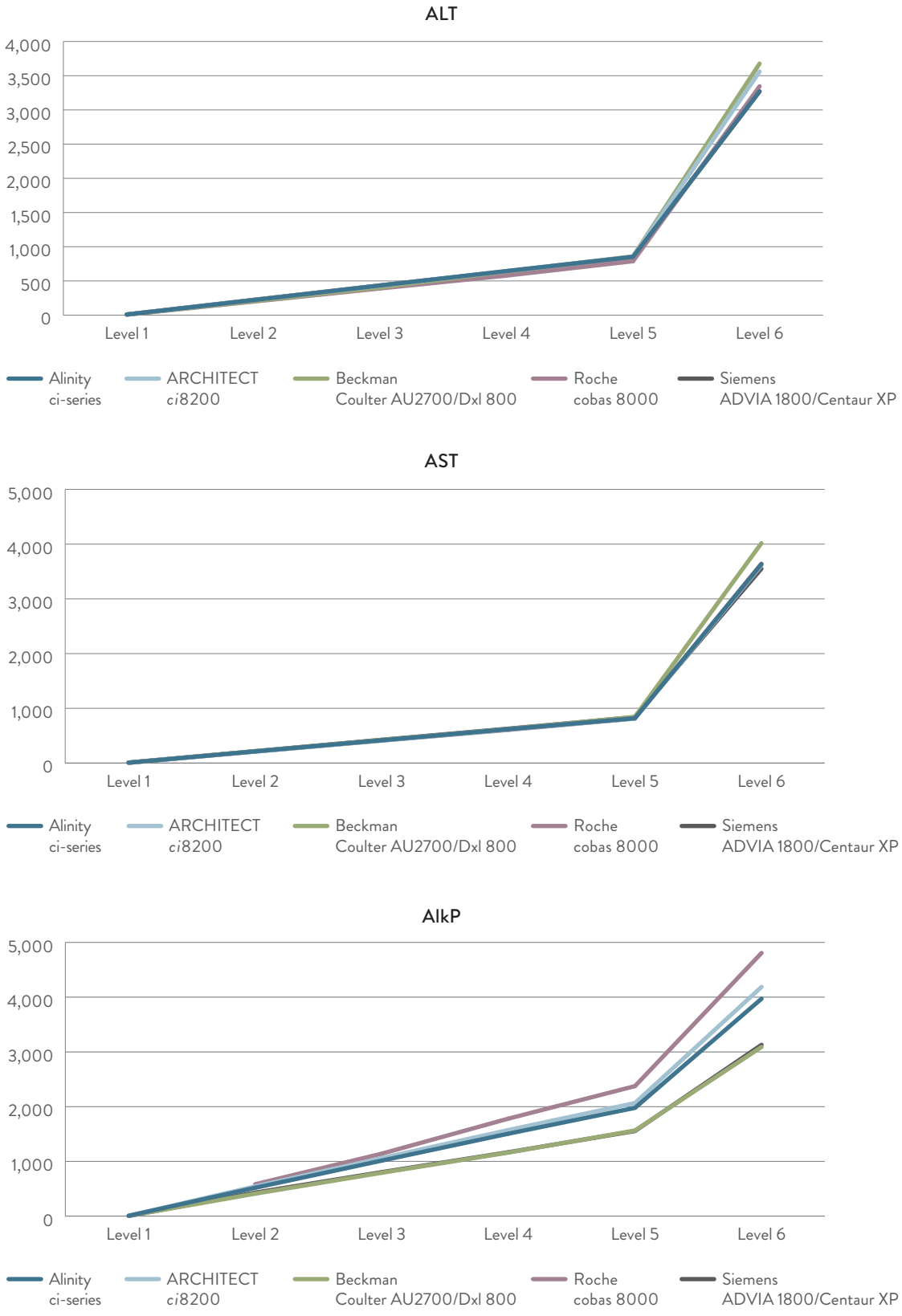
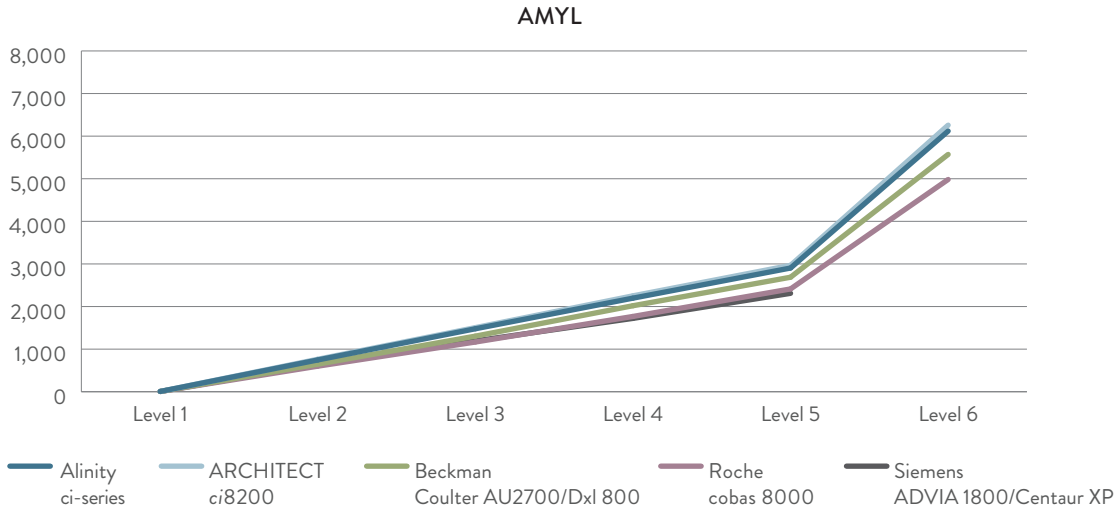


Figure 6. Results of linearity control measurement comparison curves – average of two dimensions (continued)



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