The Shift from Manual to Automated, a Cost-Benefit Analysis of the Qiagen® QIAgility® at the West Virginia State Police Forensic Laboratory

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Abstract

It was unknown if the high-throughput benefits of using the QIAgility® in a forensic DNA laboratory outweighed the costs of using and maintaining the instrument. As such, a validation and a cost-benefit study were performed at the West Virginia State Police Forensic Laboratory (WVSPFL). The validation encompassed the following studies: accuracy and precision, contamination, sensitivity, mixture, concordance, and known and non-probative. The cost-benefit study focused primarily on two factors: cost of consumables and cost of time saved by using the QIAgility®. The study determined the additional cost of consumables could potentially be offset by increasing the number of samples taken through the DNA workflow and by taking into consideration cost reductions associated with the elimination of laboratory time to process a sample. For analysts with an estimated annually salary of $40,000 and processing 50+ samples per run, the QIAgility® can be concluded as an asset if incorporated.

Introduction

Forensic laboratories are constantly seeking approaches to improve their respective DNA workflow to reduce casework backlogs and the risks of potential human error. Since the time for each case can be limited and an analyst can only handle so many samples, many laboratories have stressed the need to balance their DNA workflow to effectively process cases without introducing human error. One method is the incorporation of automation into the DNA workflow. By using automated instruments to perform the laboratory work, analysts can dedicate more time towards analyzing data and writing reports. The utilization of automation has been shown to lower the risk of potential human error in the DNA workflow, because the samples are being liquid handled by an instrument. The QIAgility® is a liquid handler manufactured by Qiagen® capable of performing DNA set-up for DNA quantitation, normalization, polymerase chain reaction (PCR) amplification, and capillary electrophoresis for a full 96-well tray in as little as thirty minutes. In addition, the instrument is manufactured with the capability to function with different chemistry kits used for DNA forensic analysis. Using the QIAgility® can help remove potential human error during protocol set-up as well as help a laboratory streamline the DNA workflow.

Materials and Methods

The following kits and instruments were used in the studies.

- Qiagen® QIAgility®
- Qiagen® EZ1® BioRobot
- Qiagen® EZ1® Advanced BioRobot XL
- Applied Biosystems® (AB®) Quantifiler® Duo Kit
- AB® 7500 Fast Real-Time® PCR system
- Promega ® PowerPlex® 16 amplification kit
- AB® GeneAmp® 9700 PCR system thermal cycler
- AB® 3130 Genetic Analyzer
- AB® GeneMapper® ID v.3.2.1

Validation Study Results

Accuracy and precision study

Table 1. Downstream effects of potential variations in accuracy and precision of the QIAgility®

Results	QIAgility® action	Initial [DNA]	DNA added	Final Volume	Final [DNA]	[DNA] for amp - 2 µl load
Expected	Pipette 100 µl	25.5 ng/µl	2 µl	102 µl	0.5 ng/µl	1 ng/µl
Observed	Pipette 103 µl	25.5 ng/µl	2 µl	105 µl	0.5 ng/µl	0.99 ng/µl
Expected	Pipette 50 µl	13 ng/µl	2 µl	52 µl	0.5 ng/µl	1 ng/µl
Observed	Pipette 53 µl	13 ng/µl	2 µl	55 µl	0.47 ng/µl	0.95 ng/µl
Observed	Pipette 49 µl	13 ng/µl	2 µl	51 µl	0.51 ng/µl	1.02 ng/µl
Expected	Pipette 25 µl	6.75 ng/µl	2 µl	27 µl	0.5 ng/µl	1 ng/µl
Observed	Pipette 25.3 µl	6.75 ng/µl	2 µl	27.3 µl	0.49 ng/µl	0.98 ng/µl
Expected	Pipette 10 µl	3 ng/µl	2 µl	12 µl	0.5 ng/µl	1 ng/µl
Observed	Pipette 10.5 µl	3 ng/µl	2 µl	12.5 µl	0.48 ng/µl	0.96 ng/µl
Observed	Pipette 9 µl	3 ng/µl	2 µl	11 µl	0.55 ng/µl	1.09 ng/µl
Expected	Pipette 2 µl	1 ng/µl	2 µl	4 µl	0.5 ng/µl	1 ng/µl
Observed	Pipette 2.5 µl	1 ng/µl	2 µl	4.5 µl	0.44 ng/µl	0.89 ng/µl
Observed	Pipette 1.8 µl	1 ng/µl	2 µl	3.8 µl	0.53 ng/µl	1.05 ng/µl

Contamination study

Analytic threshold:
100 RFU
No contaminant
0/40 TE^{-4}-Blanks

Analytic threshold:
60 RFU
No contaminant
0/40 TE^{-4}-Blanks

Analytic threshold:
25 RFU
1/40 at D18S515
11 allele at 57 RFU

Analytic threshold:
25 RFU
1/40 at D18S515
11 allele at 36 RFU

CE - reproducible

Sensitivity study

Table 2. Serial dilution of samples used in sensitivity study

Sample Name	HBM100-1	HBM100-2	HBM100-3	HBM100-4	HBM100-5	HBM100-6	HBM100-7
Concentration (ng/µl)	5.59	1.64	0.52	0.13	0.032	0.006	0.0027

Table 3. Five second injection heat map of sensitivity samples

5 SECONDS	D3S1358		TH01		D21S11		D18S51	Penta E		D5S818	D13S317		D7S820		D16S539		CSF1PO		Penta D		Amel		vWA		D8S1179		TPOX		FGA	
Sample\Allele	13	16	9	9.3	29	30	15	7	16	11	9	11	8	10	9	13	12	13	12	13	X	Y	15	17	10	12	8	10	20	21
HBM100-1.1	5173	4257	7826	7843	4724	4065	3085	1642	1062	7669	5814	5275	4261	4018	5349	4212	2636	2622	2239	2109	4534	5660	7425	6673	3927	3421	3007	3040	3108	2950
HBM100-1.2	4833	3901	7772	7798	3808	3395	3351	1538	993	7690	5272	4272	4197	3681	5010	3763	2599	2780	1967	1842	4516	5929	7004	6138	4639	3807	2893	3171	2756	2668
HBM100-1.3	5659	4816	7852	7836	4500	4363	4402	1948	1278	7683	6300	5565	5032	4733	6474	5303	3732	3175	2566	2370	5271	6623	7516	7445	5247	4321	3714	3090	3107	3256
HBM100-2.1	3589	2999	5363	4770	2918	2901	2514	1570	1164	6299	3844	3328	3242	3470	3998	3849	2620	1738	2001	1819	3581	4392	4860	4195	2789	2997	2601	2544	2724	2190
HBM100-2.2	3544	3065	4823	5602	3034	2981	2223	1552	1006	6303	3820	3027	3150	3019	3871	3005	2370	1790	1685	1579	3400	3459	4204	4550	2493	2493	2573	2250	2779	2384
HBM100-2.3	3718	3327	5592	6324	3235	3479	3190	1858	1153	7178	4220	4082	3561	3715	4634	3262	2906	2142	1774	2188	3466	4487	5510	4652	2816	2445	2480	2507	2749	2082
HBM100-3.1	1412	1134	1486	1666	1235	1078	1626	826	793	2485	1256	1117	1267	1452	1644	1293	1089	891	1198	1201	1793	2440	1869	1868	1282	879	1651	1572	1647	1370
HBM100-3.2	2008	1952	2689	3137	2524	1747	2592	1601	949	3876	2462	2003	2103	2168	2672	2673	2078	1788	1485	1620	2766	2809	1788	1906	1821	1453	1940	2217	1819	1902
HBM100-3.3	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)
HBM100-4.1	617	574	859	772	300	260	927	239	431	883	519	415	512	422	1051	593	842	514	498	446	860	1497	469	477	366	489	572	561	440	519
HBM100-4.2	514	448	924	629	531	285	872	324	615	988	457	307	594	600	816	585	657	774	682	494	681	879	217	522	375	231	825	524	532	341
HBM100-4.3	705	560	657	676	567	577	1033	1036	627	1290	592	603	439	636	1134	567	581	425	778	847	682	723	289	446	339	565	722	645	475	421
HBM100-5.1	146	107	159	156	drop	drop	71	89	75	237	179	137	101	164	263	71	115	drop	203	drop	171	118	215	86	166	drop	drop	drop	141	308
HBM100-5.2	drop	drop	94	170	74	drop	131	121	233	232	67	113	101	140	347	199	72	143	97	263	144	414	113	132	79	drop	142	337	162	drop
HBM100-5.3	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)	(ILS)
HBM100-6.1	drop	drop	99	drop	drop	drop	drop	68	75	drop	drop	drop	147	67	166	158	drop	drop	63	67	drop	88	drop	87	76	drop	104	drop	drop	92
HBM100-6.2	93	96	89	89	drop	60	135	drop	drop	91	115	80	112	72	125	drop	drop	drop	drop	89	drop	72	166	drop	drop	drop	70	125	drop	drop
HBM100-6.3	drop	70	drop	drop	drop	drop	103	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	138	drop	drop	drop	drop	drop	drop	drop	drop	drop
HBM100-7.1	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop
HBM100-7.2	drop	drop	drop	drop	drop	drop	drop	drop	drop	110	drop	drop	74	86	86	drop	drop	63	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop
HBM100-7.3	drop	60	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop	drop

Concordance study – known and non-probative samples

Table 4. Quantitated concentrations of samples set-up manually and by QIAgility®

Manual samples	Average human (ng/µl)	Average male (ng/µl)	Amplification Action	QIAgility® samples	Average human (ng/µl)	Average male (ng/µl)	Amplification action
Cig. Fil	0.103	0.14	Amp Neat	Cig. Fil	0.13	0.15	Amp Neat
Buccal_AR	8.31	0	Dilute	Buccal_AR	7.64	0	Dilute
Blood_AKG	1.04	0	Dilute	Blood_AKG	0.95	0	Dilute
Blood_KKP	6.15	0	Dilute	Blood_KKP	5.22	0	Dilute
Ecell_BEH	0.0023	0.00067	Amp Neat	Ecell_BEH	0.0023	0.00067	Amp Neat
Ecell_AKG	0.0043	0	Amp Neat	Ecell_AKG	0.003	0.0013	Amp Neat
Semen_DWM-1	21.79	20.9	Dilute	Semen_DWM-1	22.37	24.19	Dilute
Semen_DWM-2	25.12	27.14	Dilute	Semen_DWM-2	23.15	27.43	Dilute

Mixture study

Samples

- M1:F1
- M1:F3
- M1:F4
- M1:F8
- M3:F1
- M4:F1
- M8:F1

Concordant results obtained

- Quantitation
- Normalization
- Amplification

Concordance study – standard curves

Table 5. Manual-made vs QIAgility®-made standard curves

Manual Samples			QIAgility® Samples		
	Averaged R^2	Averaged Slope		Averaged R^2	Averaged Slope
Human	0.994	-3.182	Human	0.993	-3.171
Male	0.994	-3.237	Male	0.996	-3.085

Table 6. Standard Deviation of manual-made vs QIAgility®-made standard curves

Method		Std Dev. of R^2	Std Dev. of Slope
Manual	Human	0.0034	0.012
	Male	0.0025	0.026
QIAgility®	Human	0.0023	0.020
	Male	0.004	0.081

Cost-Benefit Study Results

Table 7. Total additional consumable costs and savings by using the QIAgility®

Consumable costs	80 Samples	50 Samples	30 Samples
Quantitation	$2.97	-$2.37	-$4.80
Normalization	-$7.86	-$10.14	-$8.14
Amplification	$36.75	-$5.01	-$25.6
Total	$31.86	-$17.52	-$38.54

Table 8. Total time saved by using the QIAgility®

Time difference between QIAgility® and Manual set-up	80 samples	50 samples	30 samples
Quantitation	24.5 mins	20.83 mins	10.67 mins
Normalization and Amplification	83 mins	46.5 mins	29.5 mins
Total time saved	107.5 mins	67.33 mins	40.17 mins

Table 9. Money saved by using the QIAgility® based on time and estimated annual salary of an analyst

	80 samples	50 samples	30 samples
$30,000 Annual salary ($0.25)	$26.88	$16.83	$10.04
$40,000 Annual salary ($0.34)	$36.55	$22.89	$13.66
$60,000 Annual salary ($0.51)	$54.83	$34.34	$20.49

Table 10. Total costs and savings by using the QIAgility®

	80 samples	50 samples	30 samples
$30,000 Annual salary ($0.25)	$58.74	-$0.69	-$28.50
$40,000 Annual salary ($0.34)	$68.41	$5.37	-$24.88
$60,000 Annual salary ($0.51)	$86.69	$16.82	-$18.05

Conclusions

Based on the validation studies that involved an accuracy and precision study, contamination study, sensitivity study, mixture study, and concordance study, the QIAgility® is validated for use with casework samples at WVSPFL – biochemistry section.

Based on the cost-benefit study, the costs introduced with the implementation of QIAgility® can be offset. The first factor is by increasing the number of samples taken through the DNA workflow. Respectively, taking 30 and 50 samples through the DNA workflow introduced an additional consumable cost of $38.54 and $17.52, while taking 80 samples save $31.86. The second factor is the amount of time saved by using the QIAgility®. Respectively, taking 30, 50, and 80 samples save ~ 40 minutes, ~67 minutes, and ~107 minutes. Combining these two factors and the estimated annual salary of an analyst, the total costs or savings per run from using a QIAgility® can be calculated. Dependent on those three factors, a laboratory can save $5.37 - $86.69 or introduce an additional cost of $0.69 - $28.50 by using the QIAgility ® in their DNA workflow.

References

Consumables were purchased respectively from Thomas Scientific. Thomassci.com, Qiagen®, Promega®, and Applied Biosystems®

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