J Pathol Inform

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Research Article

Utilization and utility of clinical laboratory reports with graphical elements

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Received: 26 April 12 Accepted: 21 May 12 Published: 25 August 12

This article may be cited as:
Shirts BH, Larsen N, Jackson BR. Utilization and utility of clinical laboratory reports with graphical elements. J Pathol Inform 2012;3:26.

Available FREE in open access from: http://www.jpathinformatics.org/text.asp?2012/3/1/26/100145

Abstract

Background: Graphical reports that contain charts, images, and tables have potential to convey information more effectively than text-based reports; however, studies have not measured how much clinicians value such features. We sought to identify factors that might influence the utilization of reports with graphical elements postulating that this is a surrogate for relative clinical utility of these graphical elements. **Materials and Methods:** We implemented a pilot project at ARUP laboratories to develop online enhanced laboratory test reports that contained graphical elements. We monitored on-demand clinician access to reports generated for 48 reportable tests over 22 months. We evaluated utilization of reports with graphical elements by clinicians at all institutions that use ARUP as a reference laboratory using descriptive statistics, regression, and meta-analysis tools to evaluate groups of similar test reports. **Results:** Median download rate by test was 8.6% with high heterogeneity in download rates between tests. Test reports with additional graphical elements were not necessarily downloaded more often than reports without these elements. Recently implemented tests and tests reporting abnormal results were associated with higher download rates ($P < 0.01$). Higher volume tests were associated with lower download rates ($P = 0.03$). **Conclusions:** In select cases graphical information may be clinically useful, particularly for less frequently ordered tests and in on reports of abnormal results. The utilization data presented could be used as a reference point for other laboratories planning on implementing graphical reporting. However, between-test heterogeneity was high and in many cases graphical elements may add little clinical utility, particularly if these merely reinforce information already contained in text based reports.

Key words: Clinical laboratory information systems utilization, enhanced reports, figures, LIS interface, multimedia utilization, pictures, tables

Access this article online

Website: www.jpathinformatics.org

DOI: 10.4103/2153-3539.100145

Quick Response Code:

INTRODUCTION

Several studies have shown that formatting can improve the clarity and clinical utility of pathology reports.[1-3] As the complexity of laboratory testing increases there is a growing need for well designed, intuitive reports that convey complex information to clinicians. Graphical trending of serial laboratory measures is well established in laboratory information systems and electronic medical records and its utility has been widely acknowledged;[4-6]

however, additional graphical elements are being incorporated into both paper and electronic test result reports such as specimen photographs, karyotype images, flow cytometry plots, gel images, charts of ancillary information, links to outside web-based information, and even interactive calculators.[7-9] Although graphical reports have potential to convey information more effectively than standard text-based reports, studies have not measured how much clinicians value novel graphical features in laboratory reports.[9,10] Despite the lack of data on their clinical utility; color, charts, images, and tables have become standard for reports provided by small specialty laboratories that circumvent standard interfaces between laboratory information systems and electronic medical records.[11] High-quality, color reports are often used as a selling point, although in some cases reports used as marketing tools overstate the clinical utility of novel testing modalities and actual test performance may be equivalent to or worse than standard testing.[12,13] Local and regional reference laboratories may need to implement higher quality reporting to compete; however, it is not clear if extra images and charts add clinical value, or if they are merely distractions that look nice but contribute little to clinical care. Understanding factors that influence utilization of clinical information is important to laboratories because developing and implementing each individual test report requires time and effort from laboratory directors, managers, and informatics personal in addition to infrastructure development to produce and maintain reporting systems. We sought to identify factors that might influence the utilization of reports with graphical elements beyond simple trending information postulating that this may be a surrogate for relative clinical utility of these graphical elements.

MATERIALS AND METHODS

ARUP laboratories, a national reference laboratory affiliated with the University of Utah, established pilot projects to test an enhanced electronic laboratory reporting system (EELRS) in November 2009. This was implemented as a method of providing clinicians graphical elements that cannot be transmitted or displayed with current interface systems, as a means to integrate information from multiple test reports, and as a location for links to sources of additional information.[8] This system supplements and does not replace the standard mechanisms for delivering test results. Each time a test result is verified within the laboratory information system (LIS), a pdf-format chart is generated and stored on a server. A URL (http://www.aruplab.com/Lab-Reports) along with chart id number and password are provided as a footnote to the LIS-version test result. This allows all individuals with access to standard test reports to access enhanced versions containing the same test results with graphical elements via web download. Protected health information contained within reports is stored on secure servers, and can only be accessed by those that have access to the password transmitted with reports via current interfaces. Login information linked to specific test reports allowed us to track how often these reports were accessed. We evaluated utilization of enhanced electronic laboratory reports from institutions across the United States. We evaluated instances of access to enhanced reports viewed between November 2009 and September 2011 to determine if there were characteristics of the result presentation or result content that determined how frequently clinicians accessed enhanced reports. This study was reviewed and deemed human subjects exempt by University of Utah Institutional Review Board.

Enhanced reports delivered for EELRS have been created and implemented for 62 different tests. New reports were implemented throughout the study period with 28 reports implemented in 2009, 15 implemented in 2010, and 19 implemented in 2011. For analysis, we only included tests which had been ordered at least 50 times in the study period, leaving 48 test reports: 27 implemented in 2009, 13 implemented in 2010, and 8 implemented in 2011 [Table 1]. We categorized these into groups of reports on similar tests. There were five genomic microarray tests, six maternal screening tests, and 24 cytogenetic/FISH tests. We further divided the cytogenetic/FISH tests into four subgroups: seven constitutional cytogenetic tests, four constitutional FISH panels, four oncology cytogenetic tests, and nine oncology FISH panels. 13 individual tests did not lend themselves to any obvious groupings. Beyond enabling complex reports that are not interface compatible, electronic delivery of report documents can eliminate the need to mail hard-copy forms to clients. For several tests, specifically cytogenetics tests, enhanced reports eliminated hard-copy mailing. Other enhanced reports were created specifically for online graphical presentation.

We tracked the total number of enhanced reports generated and the reports accessed at the individual report level for all institutions that ordered relevant tests throughout the study period. We only included the initial access of a report in our analysis, so multiple visits to the same report were not part of our analysis. We initially used descriptive statistical methods (median download rates for individual tests and groups) to explore the proportion of generated reports accessed for each individual test and to determine the average access rate for each test group.

It appeared that tests brought online more recently were downloaded more frequently than older tests and that higher volume tests were downloaded less often

Table 1: Overall download rates and download rates of tests with abnormal results for enhanced reports generated at ARUP laboratories

Test name	Group	% downloaded	% abnormal results downloaded	Date of enhanced report initiation	Enhanced report content
Chromosome analysis, peripheral blood (CY)	Const cytogenetics	11.2	19.2	November 2009	Image
Chromosome analysis, prod concp (CY)	Const cytogenetics	8.3	7.9	November 2009	Image
Chromosome analysis, amniotic fluid (CY)	Const cytogenetics	25.3	36.1	November 2009	Image
FISH, aneuplouidy panel	Const cytogenetics	7.2	5.7	November 2009	Image
Chromosome analysis, chorionic villus (CY)	Const cytogenetics	41.5	52.6%	November 2009	Image*
Chromosome analysis, rule out mosaicism (CY)	Const cytogenetics	7.2	30.4	November 2009	Image
Chromosome analysis, skin biopsy (CY)	Const cytogenetics	8.8	27.8	November 2009	Image
Chromosome FISH, interphase (CY)	Const FISH	9.9	10.1	November 2009	None
Chromosome FISH, metaphase (CY)	Const FISH	6.7	13.2	November 2009	None
Chromosome FISH, prenatal (CY)	Const FISH	23.4	32.5	November 2009	None
Chorionic villus, FISH	Const FISH	18.9	50.0	November 2009	None
Genomic microarray, UARRAY chip	Genomic microarray	7.8	N/A	November 2009	Image
Cytogenomic SNP microarray	Genomic microarray	4.1	N/A	September 2010	Image
Genomic microarray additional information addendum	Genomic microarray	12.5	N/A	November 2009	Image
ARRAY family confirmation study by FISH (CY)	Genomic microarray	12.5	N/A	November 2009	Image
Microarray genomic, fetal	Genomic microarray	24.0	N/A	November 2009	Image
Maternal serum screen AFP, hcg, EST, INH	Maternal screening	1.1	5.0	March 2010	Chart
Maternal serum, first trimester	Maternal screening	1.9	5.5	May 2010	Chart
Maternal screening, INT-1	Maternal screening	4.1	N/A	March 2010	Chart
Maternal screening, INT-2	Maternal screening	15.5	25.8	March 2010	Chart*
Maternal screening, sequential, spec 1	Maternal screening	5.7	18.7	March 2010	Chart
Maternal screening, sequential, spec 2	Maternal screening	4.6	18.5	March 2010	Chart
Chromosome analysis, bone marrow (CY)	Onc cytogenetics	15.0%	16.5	November 2009	Image
Chromosome analysis, leukemic blood (CY)	Onc cytogenetics	16.1	16.7	November 2009	Image
Chromosome analysis, solid tumor (CY)	Onc cytogenetics	7.8	5.3	November 2009	Image
Chromosome analysis, lymph node (CY)	Onc cytogenetics	14.0	15.0	November 2009	Image
Chromosome FISH, multiple myeloma panel (CY)	Onc FISH	7.8	9.8	November 2009	None
MDS panel by FISH	Onc FISH	3.7	5.2	March 2010	None

Table 1 *(Contd...)*

Table 1 *(Contd...)*

Test name	Group	% downloaded	% abnormal results downloaded	Date of enhanced report initiation	Enhanced report content
Chromosome FISH, CLL panel (CY)	Onc FISH	4.8	0.5	November 2009	None
PML/RARA translocation by FISH	Onc FISH	6.5	15.2	November 2009	None
Acute myelogenous leukemia panel by FISH	Onc FISH	0.5	1.0	November 2009	None*
Eosinophilia panel by FISH	Onc FISH	0.7	0.0	November 2009	None
Myeloproliferative disorders panel by FISH	Onc FISH	2.3	7.1	November 2009	None
Lymphoma (aggressive) panel by FISH	Onc FISH	12.9	26.7	March 2010	None
ALL panel by FISH, adult	Onc FISH	7.8	11.1	March 2010	None
HIV-1 genotyping	Other	8.3	N/A	November 2009	Table
Inflammatory bowel disease PRO	Other	5.7	N/A	August 2010	Table
Osmotic fragility erythrocyte	Other	20.4	N/A	November 2009	Chart
Neutrophil oxidative burst assay	Other	7.5	N/A	February 2011	Chart
LDL subclasses	Other	23.1	N/A	November 2010	Chart
Iron, liver	Other	34.5	N/A	May 2011	Image
Strain characterization - PFGE	Other	51.0	N/A	August 2010	Image
Calculi analysis with photo	Other	42.1	N/A	July 2011	Image
Oxycodone/oxymorphone confirmation urine	Other	64.8	N/A	May 2011	Chart, table
BCR-ABL1, major quantitative	Other	53.2	N/A	May 2011	Historical trend
Copper, liver	Other	36.2	43.9	May 2011	Image
Urine supersaturation	Other	5.1	10.3	August 2011	Chart, table
Opiates confirmation, urine	Other	50.8	N/A	May 2011	Chart, table*

*Example of report available in supplemental information.

than low volume tests, so we used linear regression to test if these factors influenced download rates using months from implementation as one variable and the natural log of the test volume as another continuous variable. We then used the Freeman-Tukey double arcsine transformation method for meta-analysis of proportional data as implemented by the *metaprop* function in the R-*meta* package to synthesize data, determine average download rates within group, and evaluate within-group heterogeneity. Data on chart content that could be classified as normal or abnormal was available for 31 of the 48 tests, so we also evaluated whether report content influenced download rate by comparing download rates for reports with abnormal results to overall download rates for these tests.

Enhanced reports for the 13 FISH tests were initially implemented with the intention of adding images of cells with representative marker patterns on the enhanced reports; however, due to technical issues these images were not added to the online reports during the study period. Thus, these reports presented the same information presented in traditional reports transmitted over electronic interfaces with only minor differences in formatting. So, we used two groups of FISH test reports (oncology FISH and constitutional FISH) as controls and compared these groups with other groups of tests. We used 95% confidence intervals from meta-analysis to ascertain whether download rate for groups differed significantly and differed from "negative control" FISH testing download rates.

We evaluated categories of graphics presented in enhanced reports in order to better understand between-test heterogeneity in download rates. We thought that different types of graphics might explain why certain reports were downloaded more than others. We present several examples of enhanced reports to illustrate examples with high and low download rates.

RESULTS

During the study period starting at the implementation of EELRS on November 9, 2009 and ending September 30, 2011 around 174,170 enhanced reports were generated for the 48 reportable tests evaluated [Table 1]. The majority of enhanced reports generated were maternal screening reports (66.4%), after this the next most represented group was oncology cytogenetics (6.2% of reports), followed by constitutional cytogenetics reports (5.6%), constitutional fish panel reports (2.5%), oncology fish (2.1%), and genomic microarray reports

(1.4%). 15.8% of generated reports were for the 13 individual tests which not lend themselves to any obvious groupings [Table 1]. For all generated reports 8,947 were downloaded for a total download rate of 5.1%. However, the highest volume tests had low download rates, so the median test download rate was 8.6% and several tests had much higher download rates so the estimated average test download rate was 13.3% [Table 2].

Both time from implementation and number of total tests ordered were significantly associated with download rate. More recently implemented tests were associated with higher download rates, with download rates declining by 5% to 10% in the first six months after a new report is implemented ($P < 0.001$ for trend). Higher volume tests were downloaded at a rate lower than low volume tests, with download rates declining by about 2% per order of magnitude of test volume ($P = 0.03$). Reports indicating abnormal test results were also downloaded on average 8% more often than reports indicating normal results ($P < 0.01$).

All groups of tests except the Maternal Serum Screening group had significantly higher download rates than the Oncology FISH control group ($P < 0.05$). However, only the "other" group had a significantly higher download rate than the Constitutional FISH control group ($P < 0.05$). There was striking overall heterogeneity in download rates between tests ($P < 0.001$ for heterogeneity). Even when we examined tests in the same group, there was substantial within group heterogeneity ($P < 0.001$ for within group analysis of heterogeneity for all groups except Oncology Cytogenetics, $P = 0.198$, see Table 2). This high level of within group heterogeneity tempers any conclusions that might be drawn from between group comparisons. Although download rates differed from test to test and group to group, there were no clear factors beyond those noted above that correlated with download rate. We present and discuss selected examples of representative reports below.

Specific Examples of Report Groups

Maternal serum screening reports

Maternal serum screening tests were the highest volume tests with enhanced reports. The enhanced report graphically displays likelihood ratios compared to decision cutoffs [Figure 1]. This group of reports had among the lowest download rates (4.7% average by meta-analysis, Table 2). A positive or abnormal serum screen was associated with a substantially higher report download rate (13.2%). The most frequently ordered test was the maternal serum screen with AFP, hCG, EST, INH (quad screen) which had an overall download rate of 1.1%, and a download rate of 5.0% for tests reporting positive screening.

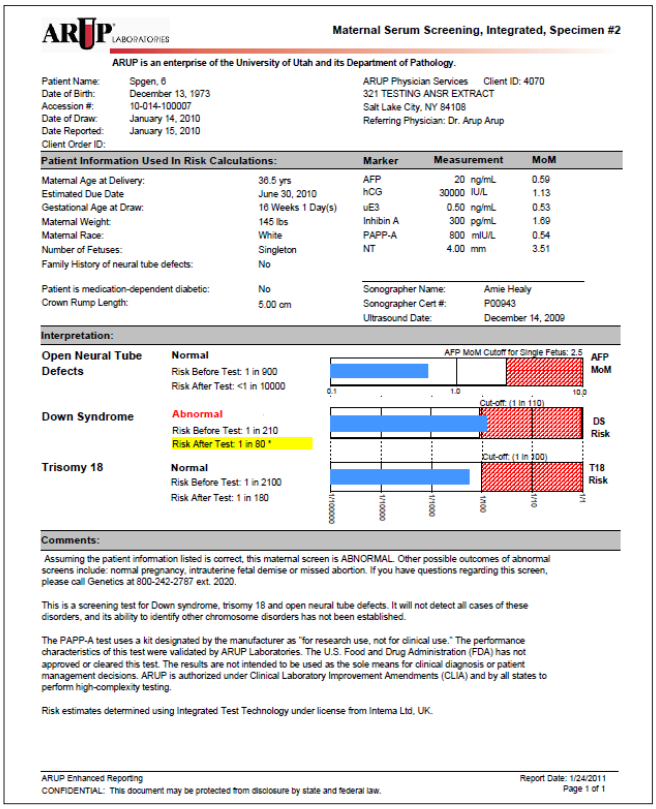
FISH reports

PDF reports for FISH testing displayed the standard information that would be transmitted over an electronic interface with standard formatting and a color logo [Figure 2]. Despite this lack of additional information, there was substantial heterogeneity in download rates for FISH reports (P for heterogeneity < 0.001); with rates varying between 23.4% and 0.5% [Tables 1 and 2]. Reports on FISH for suspected malignancies were downloaded less than FISH reports for constitutional abnormalities (4.6% and 13.8% respectively). Overall oncology FISH reports with abnormal results were downloaded only slightly more often than those with normal results (7.1% and 4.6% respectively), and reports with abnormal constitutional FISH results were downloaded more often than reports with normal constitutional FISH findings (19.2% and 13.8% respectively), but neither of these differences were significant.

Table 2: Summary statistics for enhanced report download rates by category of laboratory tests

Group	N	Overall %	Median %	High %	Low %	Average* %	95% CI *	*P* value for within group heterogeneity*	Average, abnormal results * %	95% CI *
All tests	48	5.1	8.6	64.8	0.5	13.3	(10.6%; 16.3%)	<0.0001	-	-
Const cytogenetics	7	12.3	8.8	41.5	7.2	14.5	(9.3%; 20.7%)	<0.0001	22.3	(13.2%; 33.0%)
Const FISH	4	10.9	14.4	23.4	6.7	13.8	(7.7%; 21.3%)	<0.0001	19.2	(8.5%; 32.9%)
Genomic microarray	5	7.4	12.5	24.0	4.1	10.4	(6.3%; 15.3%)	<0.0001	-	-
Maternal screen	6	2.1	4.4	15.5	1.1	4.7	(1.7%; 9.1%)	<0.0001	13.2	(6.7%; 21.5%)
Onc cytogenetics	4	15.0	14.5	16.1	7.8	14.7	(12.7%;16.9%)	0.198	15.7	(12.7%; 19.1%)
Onc fish	9	5.5	4.8	12.9	0.5	4.6	(2.8%;6.8%)	<0.0001	7.1	(2.7%; 13.2%)
other	13	10.2	34.5	64.8	5.1	27.9	(21.4%; 34.9%)	<0.0001	-	-

*From synthesis of proportional data using meta-analysis



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Maternal Serum Screening, Integrated, Specimen #2

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Patient Name: Spgen, 6
Date of Birth: December 13, 1973
Accession #: 10-014-100007
Date of Draw: January 14, 2010
Date Reported: January 15, 2010
Client Order ID:

ARUP Physician Services Client ID: 4070
321 TESTING ANSR EXTRACT
Salt Lake City, NY 84108
Referring Physician: Dr. Arup Arup

Patient Information Used In Risk Calculations:		Marker	Measurement	MoM
Maternal Age at Delivery:	36.5 yrs	AFP	20 ng/mL	0.59
Estimated Due Date	June 30, 2010	hCG	30000 IU/L	1.13
Gestational Age at Draw:	16 Weeks 1 Day(s)	uE3	0.50 ng/mL	0.53
Maternal Weight:	145 lbs	Inhibin A	300 pg/mL	1.69
Maternal Race:	White	PAPP-A	800 mIU/L	0.54
Number of Fetuses:	Singleton	NT	4.00 mm	3.51
Family History of neural tube defects:	No			
Patient is medication-dependent diabetic:	No	Sonographer Name:	Amie Healy	
Crown Rump Length:	5.00 cm	Sonographer Cert #:	P00943	
		Ultrasound Date:	December 14, 2009	

Interpretation:

Open Neural Tube Defects — Normal
Risk Before Test: 1 in 900
Risk After Test: <1 in 10000

Down Syndrome — Abnormal
Risk Before Test: 1 in 210
Risk After Test: 1 in 80 *

Trisomy 18 — Normal
Risk Before Test: 1 in 2100
Risk After Test: 1 in 180

Comments:

Assuming the patient information listed is correct, this maternal screen is ABNORMAL. Other possible outcomes of abnormal screens include: normal pregnancy, intrauterine fetal demise or missed abortion. If you have questions regarding this screen, please call Genetics at 800-242-2787 ext. 2020.

This is a screening test for Down syndrome, trisomy 18 and open neural tube defects. It will not detect all cases of these disorders, and its ability to identify other chromosome disorders has not been established.

The PAPP-A test uses a kit designated by the manufacturer as "for research use, not for clinical use." The performance characteristics of this test were validated by ARUP Laboratories. The U.S. Food and Drug Administration (FDA) has not approved or cleared this test. The results are not intended to be used as the sole means for clinical diagnosis or patient management decisions. ARUP is authorized under Clinical Laboratory Improvement Amendments (CLIA) and by all states to perform high-complexity testing.

Risk estimates determined using Integrated Test Technology under license from Intema Ltd, UK.

Figure 1: Example enhanced report for maternal serum screening

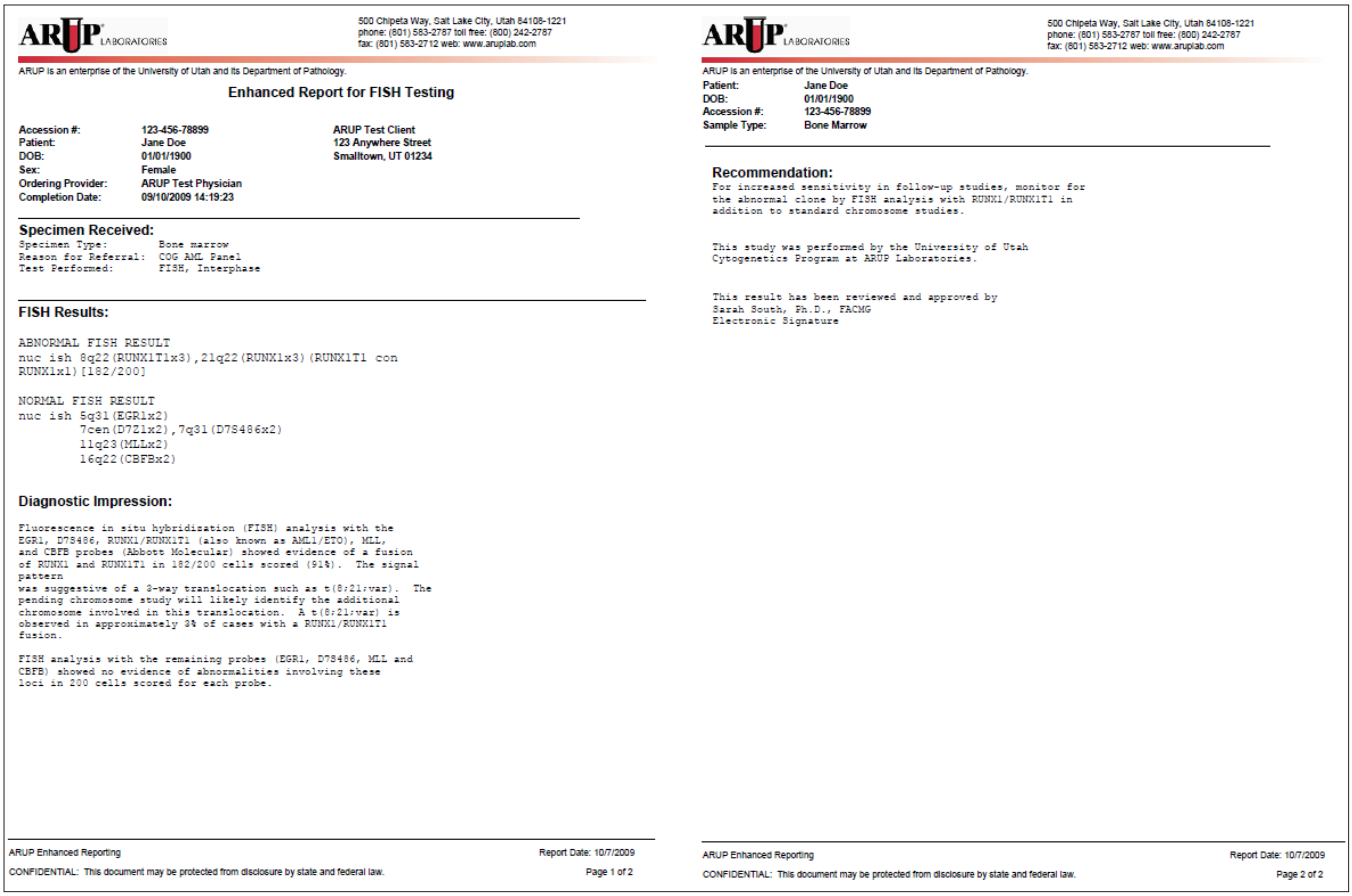
Cytogenetic test reports

In the past, images of karyotypes were mailed or faxed to clinicians. Enhanced cytogenetics test reports replaced paper images of karyotypes with PDF reports accessible online [Figure 3]. Cytogenetic test results for constitutional chromosomal abnormalities were downloaded as often as FISH reports for constitutional abnormalities (14.5% and 13.8% respectively). Although cytogenetic reports with karyotypes for oncology testing were downloaded more often than similar FISH reports for oncology testing (14.7% and 4.6% respectively), download rates for abnormal tests were not significantly higher than overall download rates in this group [Table 2].

Drug screening reports

Several ungrouped tests were ordered most frequently [Table 1]. Among those with the highest download rates were drug screening test reports that presented information on metabolic pathways [Figure 4], BRC-ABL testing reports showing historical trend information, and calculi analysis reports with photographs of the calculi.

Additional example reports for several tests evaluated in this manuscript can be found at http://www.aruplab.com/AboutARUP/PressRoom/Articles_LandingPages/enhanced_laboratory_reporting.jsp.



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Enhanced Report for FISH Testing

Accession #: 123-456-78899
Patient: Jane Doe
DOB: 01/01/1900
Sex: Female
Ordering Provider: ARUP Test Physician
Completion Date: 09/10/2009 14:19:23

ARUP Test Client
123 Anywhere Street
Smalltown, UT 01234

Specimen Received:

Specimen Type: Bone marrow
Reason for Referral: COG AML Panel
Test Performed: FISH, Interphase

FISH Results:

ABNORMAL FISH RESULT
nuc ish 8q22(RUNX1T1x3),21q22(RUNX1x3)(RUNX1T1 con
RUNX1x1)[182/200]

NORMAL FISH RESULT
nuc ish 5q31(EGR1x2)
7cen(D7Z1x2),7q31(D7S486x2)
11q23(MLLx2)
16q22(CBFBx2)

Diagnostic Impression:

Fluorescence in situ hybridization (FISH) analysis with the EGR1, D7S486, RUNX1/RUNX1T1 (also known as AML1/ETO), MLL, and CBFB probes (Abbott Molecular) showed evidence of a fusion of RUNX1 and RUNX1T1 in 182/200 cells scored (91%). The signal pattern was suggestive of a 3-way translocation such as t(8;21;var). The pending chromosome study will likely identify the additional chromosome involved in this translocation. A t(8;21;var) is observed in approximately 8% of cases with a RUNX1/RUNX1T1 fusion.

FISH analysis with the remaining probes (EGR1, D7S486, MLL and CBFB) showed no evidence of abnormalities involving these loci in 200 cells scored for each probe.

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Patient: Jane Doe
DOB: 01/01/1900
Accession #: 123-456-78899
Sample Type: Bone Marrow

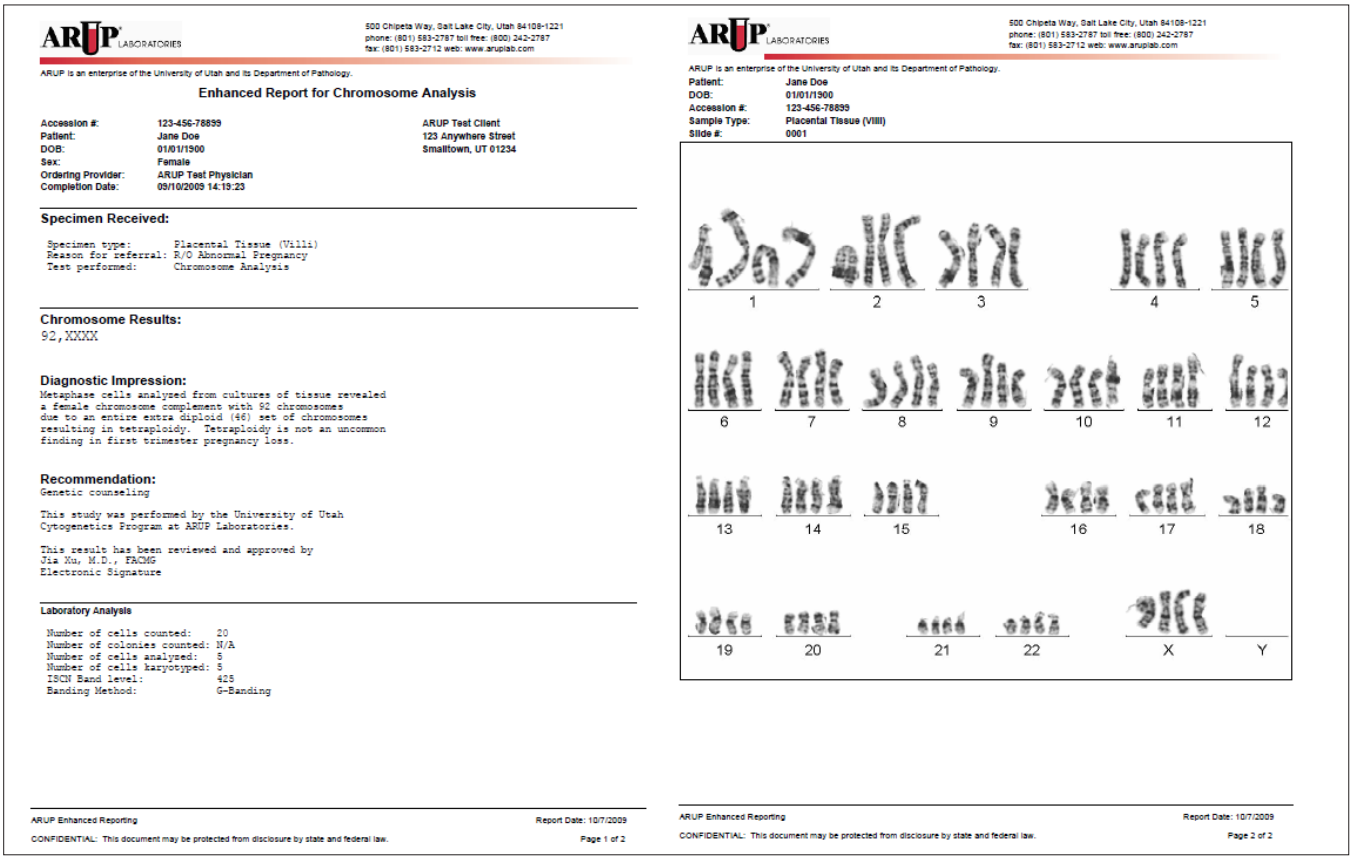
Recommendation:

For increased sensitivity in follow-up studies, monitor for the abnormal clone by FISH analysis with RUNX1/RUNX1T1 in addition to standard chromosome studies.

This study was performed by the University of Utah Cytogenetics Program at ARUP Laboratories.

This result has been reviewed and approved by
Sarah South, Ph.D., FACMG
Electronic Signature

Figure 2: Example enhanced report for FISH testing



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Enhanced Report for Chromosome Analysis

Accession #:	123-456-78899	ARUP Test Client	
Patient:	Jane Doe	123 Anywhere Street	
DOB:	01/01/1900	Smalltown, UT 01234	
Sex:	Female		
Ordering Provider:	ARUP Test Physician		
Completion Date:	09/10/2009 14:19:23		

Specimen Received:

Specimen type: Placental Tissue (Villi)
Reason for referral: R/O Abnormal Pregnancy
Test performed: Chromosome Analysis

Chromosome Results:

92,XXXX

Diagnostic Impression:

Metaphase cells analyzed from cultures of tissue revealed a female chromosome complement with 92 chromosomes due to an entire extra diploid (46) set of chromosomes resulting in tetraploidy. Tetraploidy is not an uncommon finding in first trimester pregnancy loss.

Recommendation:

Genetic counseling

This study was performed by the University of Utah Cytogenetics Program at ARUP Laboratories.

This result has been reviewed and approved by Jia Xu, M.D., FACMG
Electronic Signature

Laboratory Analysis

Number of cells counted: 20
Number of colonies counted: N/A
Number of cells analyzed: 5
Number of cells karyotyped: 5
ISCN Band level: 425
Banding Method: G-Banding

ARUP Enhanced Reporting Report Date: 10/7/2009
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ARUP is an enterprise of the University of Utah and its Department of Pathology.

Patient: Jane Doe
DOB: 01/01/1900
Accession #: 123-456-78899
Sample Type: Placental Tissue (VIII)
Slide #: 0001

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 X Y

ARUP Enhanced Reporting Report Date: 10/7/2009
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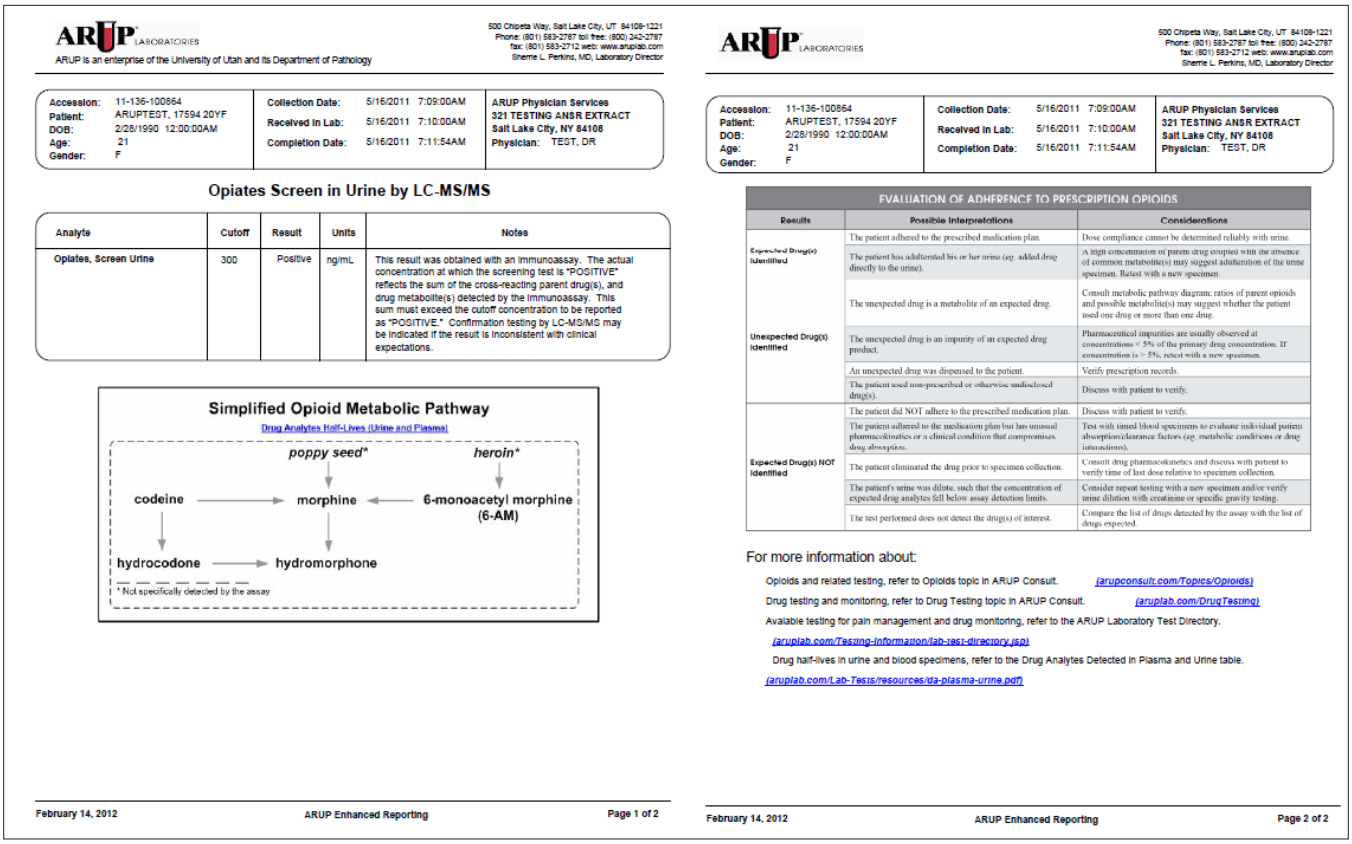
Figure 3: Example enhanced report for cytogenetic testing



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Sherrie L. Perkins, MD, Laboratory Director

Accession:	11-136-100864	**Collection Date:**	5/16/2011 7:09:00AM	**ARUP Physician Services**	
Patient:	ARUPTEST, 17594 20YF	**Received In Lab:**	5/16/2011 7:10:00AM	**321 TESTING ANSR EXTRACT**	
DOB:	2/28/1990 12:00:00AM	**Completion Date:**	5/16/2011 7:11:54AM	**Salt Lake City, NY 84108**	
Age:	21			**Physician:**	TEST, DR
Gender:	F				

Opiates Screen in Urine by LC-MS/MS

Analyte	Cutoff	Result	Units	Notes
Opiates, Screen Urine	300	Positive	ng/mL	This result was obtained with an immunoassay. The actual concentration at which the screening test is "POSITIVE" reflects the sum of the cross-reacting parent drug(s), and drug metabolite(s) detected by the immunoassay. This sum must exceed the cutoff concentration to be reported as "POSITIVE." Confirmation testing by LC-MS/MS may be indicated if the result is inconsistent with clinical expectations.

Simplified Opioid Metabolic Pathway

Drug Analytes Half-Lives (Urine and Plasma)

poppy seed* heroin*
codeine morphine 6-monoacetyl morphine (6-AM)
hydrocodone hydromorphone
* Not specifically detected by the assay

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ARUP LABORATORIES

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Accession:	11-136-100864	**Collection Date:**	5/16/2011 7:09:00AM	**ARUP Physician Services**	
Patient:	ARUPTEST, 17594 20YF	**Received In Lab:**	5/16/2011 7:10:00AM	**321 TESTING ANSR EXTRACT**	
DOB:	2/28/1990 12:00:00AM	**Completion Date:**	5/16/2011 7:11:54AM	**Salt Lake City, NY 84108**	
Age:	21			**Physician:**	TEST, DR
Gender:	F				

EVALUATION OF ADHERENCE TO PRESCRIPTION OPIOIDS

Results	Possible Interpretations	Considerations
Expected Drug(s) Identified	The patient adhered to the prescribed medication plan.	Dose compliance cannot be determined reliably with urine.
	The patient has adulterated his or her urine (eg, added drug directly to the urine).	A high concentration of parent drug coupled with the absence of common metabolite(s) may suggest adulteration of the urine specimen. Retest with a new specimen.
	The unexpected drug is a metabolite of an expected drug.	Consult metabolic pathway diagram; ratios of parent opioids and possible metabolite(s) may suggest whether the patient used one drug or more than one drug.
Unexpected Drug(s) Identified	The unexpected drug is an impurity of an expected drug product.	Pharmaceutical impurities are usually observed at concentrations < 5% of the primary drug concentration. If concentration is > 5%, retest with a new specimen.
	An unexpected drug was dispensed to the patient.	Verify prescription records.
	The patient used non-prescribed or otherwise undisclosed drug(s).	Discuss with patient to verify.
Expected Drug(s) NOT Identified	The patient did NOT adhere to the prescribed medication plan.	Discuss with patient to verify.
	The patient adhered to the medication plan but has unusual pharmacokinetics or a clinical condition that compromises drug absorption.	Test with timed blood specimens to evaluate individual patient absorption/clearance factors (eg, metabolic conditions or drug interactions).
	The patient eliminated the drug prior to specimen collection.	Consult drug pharmacokinetics and discuss with patient to verify time of last dose relative to specimen collection.
	The patient's urine was dilute, such that the concentration of expected drug analytes fell below assay detection limits.	Consider repeat testing with a new specimen and/or verify urine dilution with creatinine or specific gravity testing.
	The test performed does not detect the drug(s) of interest.	Compare the list of drugs detected by the assay with the list of drugs expected.

For more information about:

Opioids and related testing, refer to Opioids topic in ARUP Consult. (arupconsult.com/Topics/Opioids)

Drug testing and monitoring, refer to Drug Testing topic in ARUP Consult. (aruplab.com/DrugTesting)

Available testing for pain management and drug monitoring, refer to the ARUP Laboratory Test Directory. (aruplab.com/Testing-Information/lab-test-directory.jsp)

Drug half-lives in urine and blood specimens, refer to the Drug Analytes Detected in Plasma and Urine table. (aruplab.com/Lab-Tests/resources/da-plasma-urine.pdf)

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Figure 4: Example enhanced report for opiate confirmatory testing

DISCUSSION

Understanding factors that influence utilization of graphical elements on laboratory reports can facilitate efficient and effective communication of information.[10] Our study attempts to determine the potential clinical importance of graphical information by using report access as a surrogate for report utility. We believe utilization is a reasonable, objective surrogate for utility; however, we acknowledge that there are major limitations to this assertion. Our assumption could be confounded by several common practices such as office staff downloading all enhanced reports or instructions for access being lost, hidden, or difficult to find because of interface formatting. Furthermore, our study evaluated utilization across many institutions that use AURP as a reference laboratory so much of the heterogeneity in utilization may be due to institution specific practices. As with any measure of subjective value, utility is context dependent and difficult to measure accurately. However, to our knowledge, there are no other published studies that examine the utility or utilization of graphical report elements in the clinical laboratory setting, beyond reports that evaluate the utility of trending information for numeric tests, suggesting that these measures of utility and utilization could serve as a useful baseline for other laboratories planning on implementing graphical reporting. We have received comments from clinicians that they would like to know what additional benefit is provided in the enhanced report so they can determine whether it is worthwhile to download the report, suggesting that clinicians are thinking about laboratory information in a way that is consistent with utilization being a surrogate for clinical utility.

Our experience with 48 custom build reports, as presented here, shows that custom report access rates were often low, but varied widely from test to test. Despite this heterogeneity, we observed several significant trends in download rates that might shed light on clinician behavior and help laboratory medical directors evaluate how often the addition of a graphical element might be clinically useful. Recently implemented reports were downloaded more often than older reports, reports for more frequently ordered tests were downloaded less than reports for more frequently ordered tests, and reports with abnormal results were downloaded more often than reports with normal results. Each of these observations may illustrate clinical learning patterns. Many clinicians are curious about new information, and once they have ascertained what is in a report they do not take the time to access it again if it is unlikely to add value. However, knowing that the information is available, clinicians may then access it again when they come across an abnormal or unexpected result. This suggests that in most cases implementing graphical reports for novel tests may be better received than adding graphical elements to existing test reports.

Download rates for the majority of individual reports generated were below 10% suggesting that for most clinicians formatting and color images are not important enough to justify the time necessary to download the reports. On the other hand, several reports were accessed at much higher rates suggesting that there are instances where graphical elements on reports present valuable information that may be impossible to convey over current interfaces. Also, the fact that reports associated with positive or abnormal tests are accessed more than negative reports suggests that the need for added information may be situational and case specific.

In conclusion, our analysis suggests that color images and other graphical elements in many cases do not enhance the utility of clinical laboratory reports. However, in some cases additional graphical information may be useful to clinicians, particularly for less frequently ordered tests where the interpretation of text results may not be as apparent from text base reports. The utilization data presented could be used as a reference point for estimating future utilization rates for laboratories planning on implementing graphical reporting. However, substantial observed heterogeneity suggests laboratory directors should not be surprised when graphical elements are not received as they expected. Laboratory directors should also consider carefully the expected clinical benefit of information display methods before redesigning reports in the face of presumed market pressure. In addition, non-laboratory clinicians could be more aware of what information from laboratory testing they are using for clinical decisions and base their choice of laboratory testing primarily on the quality of the information rather than the presentation of this information.

ACKNOWLEDGEMENTS

The authors would like to thank Becky Chestnut for her assistance in technical writing and editing this manuscript.

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