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Variation in interoperability across clinical laboratories nationwide

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Abstract

Objective: To characterize nationwide variation and factors associated with clinical laboratories': (1) capabilities to send structured test results electronically to ordering practitioners' EHR systems; and (2) their levels of exchange activity, as measured by whether they sent more than three-quarters of their test results as structured data to ordering practitioners' EHR systems.

Materials and methods: A national survey of all independent and hospital laboratories was conducted in 2013. Using an analytic weighted sample of 9382 clinical laboratories, a series of logistic regression analyses were conducted to identify organizational and area characteristics associated with clinical laboratories' exchange capability and activity.

Results: Hospital-based clinical laboratories (71%) and larger clinical laboratories (80%) had significantly higher levels of capability compared to independent (58%) and smaller laboratories (48%), respectively; though all had similar levels of exchange activity, with 30% of clinical laboratories sending 75% or more of their test results electronically. In multivariate analyses, hospital and the largest laboratories had 1.87 and 4.40 higher odds, respectively, of possessing the capability to send results electronically compared to independent laboratories ($p < 0.001$). Laboratories located in areas with a higher share of potential exchange partners had a small but significantly greater capability to send results electronically and higher levels of exchange activity($p < 0.05$).

Conclusion: Clinical laboratories' capability to exchange varied by size and type; however, all clinical laboratories had relatively low levels of exchange activity. The role of exchange partners potentially played a small but significant role in driving exchange capability and activity.

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Author contributions

All authors have made substantial contributions to all of the following: (1) the conception and design of the study, or acquisition of data, or analysis and interpretation of data, (2) drafting the article or revising it critically for important intellectual content, (3) final approval of the version to be submitted.

Conflicts of interest

None.

Keywords

Health information technology; Electronic health records; Clinical laboratories; Interoperability; Health information exchange; Standards

1. Background and significance

Laboratory test results influence a majority of medical decisions [1]. However, care providers must receive the test results in a timely manner in order to inform their clinical decision-making. When care providers fail to follow-up on abnormal test results, patients are at an increased risk of misdiagnoses or delayed treatment, leading to suboptimal clinical outcomes [2]. Patients with pending test results at the time of hospital discharge may require prompt action [3]. Although the timely exchange of such laboratory results is critical, deficits in communication among providers continue to be endemic [4]. Timely receipt and follow-up of laboratory test results is essential to improve patient safety and care quality.

Increasing interoperability of laboratory data—the electronic capture, storing, and transmitting of test results in structured formats of discrete data using controlled vocabulary—may improve the timely delivery of test results to health care providers. Results stored in a provider's electronic health record (EHR) can improve providers' documentation and time to follow-up with patients regarding abnormal test results [5,6]. Additionally, clinical decision support functionalities using structured test results can alert providers to abnormal test results [7,8]. Electronic laboratory result viewing is independently associated with higher care quality among small group practices [9]. Structured test results can also enhance the sharing of information across care settings and systems, thereby potentially reducing redundant tests and increasing efficiency [10,11].

In addition to the clinical benefits of laboratory interoperability, there are important secondary uses of laboratory data from EHRs, such as for tracking public health emergencies, enabling efficient medical research, and facilitating the transmittal and use of data across medical devices and EHR systems [12]. For example, efforts such as the Interop V-Lab and the U.S. Patient Centered Outcomes Research Institute envision leveraging such data to facilitate research across consortiums and other partners [13,14]. Ultimately, greater interoperability is seen as essential to supporting a learning health system [15].

In the U.S., national and state-level efforts have been under way to support interoperability of laboratory data. Beginning in 2011, the Centers for Medicare & Medicaid Services' (CMS) Medicare and Medicaid EHR Incentive Programs provided financial incentives to eligible professionals and hospitals to adopt and "meaningfully" use certified EHR technology with the capability to incorporate laboratory test results [16]. Specifically, certified EHR technology had to be capable of electronically receiving, incorporating, and displaying clinical laboratory tests and values in accordance with the HL7 Version 2.5.1 and laboratory tests had to be capable of being represented using LOINC codes [17]. The Office of the National Coordinator for Health IT (ONC) launched the State Health Information Exchange (HIE) Cooperative Agreement Program in order to support electronic exchange of health information, including laboratory data. Many states served as health information

exchange organizations (HIOs), connected regional HIOs, or partnered with local exchange networks, resulting in more than half of states directly offering or enabling electronic laboratory results delivery, which involves electronically sending test results directly to the provider's EHR [18,19]. More recently, ONC outlined a strategy to enhance interoperability across settings and systems, including clinical laboratories [20].

Although efforts to support interoperability of laboratory data have been underway, limited information exists concerning clinical laboratories' interoperability. Based upon a national survey of clinical laboratories conducted in 2013, about 6 in 10 possessed the capability to send structured test results electronically, and less than half (3 in 10 overall) sent more than three-quarters of their test results as structured data to ordering practitioners' EHR systems [21]. However, it is unknown as to how interoperability varies across clinical laboratories. This study sought to identify organizational and area characteristics associated with clinical laboratories' capability and sending of test results as structured data to ordering practitioners' EHR systems. We also examine the potential role that the Medicare and Medicaid EHR Incentive Programs and clinical laboratories' participation in HIOs played in enabling laboratories' interoperability.

2. Materials and methods

2.1. Data collection

The National Survey on HIE in Clinical Laboratories was conducted by NORC at the University of Chicago as part of the evaluation of the State HIE Cooperative Agreement Program. The CMS Online Survey, Certification and Reporting (OSCAR) database was the source for the sampling frame, which consisted of a census of all independent and hospital laboratories. Laboratories conducting only tests of minimal complexity, categorized as waived tests,[1] were ineligible for the survey. NORC administered the survey to 11,371 clinical laboratories, comprised of 7421 hospital laboratories and 4130 independent laboratories from January through May 2013. The overall weighted response rate for clinical laboratories was 43.2%. The weighted response rate was 44.0% among hospital laboratories and 41.8% among independent laboratories.

The mail survey, which was cognitively tested, was developed based upon existing state-level surveys and input from subject matter experts. Separate surveys, with a common set of core items, were developed for hospital-based laboratories and independent laboratories. Copies of the surveys are included in the appendix. Non-respondents received follow-up mailings and phone calls to encourage response. NORC created a computer-assisted telephone interviewing (CATI) instrument to capture telephone responses in order to increase the response rates. The CATI consisted of eight critical items, which were provided to 784 mail survey non-responders. Copies of the surveys and CATI instrument are included in the appendix. Laboratories were requested to provide answers for the 2012 calendar year.

[1]As defined by Clinical Laboratory Improvement Amendments (CLIA), waived tests are categorized as "simple laboratory examinations and procedures that have an insignificant risk of an erroneous result."

The large chain independent laboratories, LabCorp and Quest laboratories were sampled with certainty given the large volume of tests conducted by these two organizations, and data collection for these laboratories was carried out centrally through headquarters rather than through the individual laboratories.

2.2. Outcomes

Two outcomes were examined: whether a laboratory is capable of sending test results electronically and whether a laboratory sent 75% or more of its test results electronically among laboratories that indicated they were capable of sending electronic records. A laboratory's capability to electronically send test results was measured by their response to the following item: "Is your laboratory currently capable of sending test results electronically in a structured format (that is, using the HL7 messaging standard and a vocabulary standard such as LOINC) to an ordering practitioner's?" The standards mentioned relate to certification requirements. There were other survey items that assessed the specific type of standards used by laboratories; however, there were high levels of non-response for those items and therefore these are not reported. Exchange activity was calculated using survey items related to the total volume of test results sent and the volume of test results sent electronically in a structured format to ordering practitioners' EHRs. We chose to examine this outcome as a discrete rather than continuous variable due to the highly skewed distribution of the data. We defined laboratories' success as sending greater than 75% of tests electronically.

2.3. Independent variables

Laboratory size was calculated by dividing the total volume of test results into quartiles. The total volume of test results sent was considerably higher for hospital laboratories compared to independent laboratories, so lab size quartiles were computed separately for hospital and independent laboratories. We also examined laboratory type and affiliation. Setting (e.g., rural, urban) was determined by whether the clinical laboratory was located in a metropolitan statistical area.

In order to assess the potential availability of exchange partners for clinical laboratories to send test results to an ordering practitioners' EHR, using data from the Medicare and Medicaid EHR Incentive Programs, we calculated the share of eligible professionals paid by county for completing the first stage of the program. Providers who completed the first stage of the program had EHRs with the capability to incorporate laboratory test results. For hospital laboratories, using data from American Hospital Association (AHA) Health IT Supplement survey conducted in 2013 (but reflecting the calendar year 2012), we merged data regarding whether the hospital had a basic EHR and/or participated in HIO. Using data from the main AHA survey from that same year, we examined whether the hospital (or system) offered a health maintenance organization (HMO) product and constructed a measure of market concentration, known as the Herfindahl-Hirschman Index [22]. Greater competition as well as market consolidation has been shown to be associated with lower rates of electronic exchange of health information among hospitals [23,24]. Hospitals offering HMO products possess financial reasons for sharing information to better manage

and coordinate patient care, and have been found to be more likely to electronically exchange health information [25].

2.4. Analysis

The analytical sample consisted of mail respondents and the chain laboratories (LabCorp and Quest); among these the respondents, the sample was further limited to laboratories that could be successfully merged with the other data sets. The analytic sample did not include CATI responses because this was an abbreviated survey, which did not include all the variables of interest for this analysis.

Separate analyses were conducted on hospital laboratories (weighted N = 6082), independent laboratories (weighted N = 2874), and on a pooled sample of hospital and independent laboratories (weighted N = 9382). The total unweighted sample consisted of 3471 laboratories, including 986 independent laboratories and 2341 hospital laboratories. All computations were completed using SAS software Version 9.3 (Cary, North Carolina). Multiple imputation was used to address missing data for the variables related to the two outcomes. A multiple imputation software package IVEware was used [26].

Univariate weighted frequencies and means were calculated for the descriptive analysis. We conducted a series of multivariate logistic regression to identify predictors of whether a laboratory is capable of sending test results electronically across all laboratories and then separately for each type (hospital and independent). The second set of models identifies predictors of whether a laboratory sent 75% or more of its test results electronically among laboratories that indicated they were capable of sending electronic records. Again, this was examined across all clinical laboratories and then by type of laboratory.

3. Results

3.1. Characteristics of the respondents

Hospital laboratories represented two-thirds (68%) of the respondents (n = 9382); the remaining third (32%) were independent laboratories (Table 1). The mean share of potential exchange partners across the counties of responding laboratories, as measured by the percent of eligible professionals paid for attesting to the first stage the Medicare and Medicaid EHR Incentive Programs in 2011 and 2012, was about one-quarter (23%).

Close to half of the independent laboratories were commercial laboratories (47%), while more than one in five belonged to a clinic or group practice (22%). Among hospital laboratories, approximately half (53%) were part of not-for-profit hospitals or a larger hospital system (55%). At the time the survey was conducted, a minority of hospital laboratories were part of hospitals that participated in a HIO (18%) or had adopted a basic EHR system (29%).

Laboratory size, as measured by the total volume of test results sent (whether via paper or electronically) was considerably higher for hospital laboratories than for independent laboratories. For example, among the highest volume laboratories, hospital laboratories sent

greater than 751,058 test results whereas independent laboratories sent greater than 143,050 test results in 2012.

3.2. Exchange capability among clinical laboratories

In 2012, 62% of clinical laboratories possessed the capability to send test results electronically (Fig. 1). Hospital-based clinical laboratories (71%) and larger clinical laboratories (80%) had significantly higher levels of capability compared to independent (58%) and smaller laboratories (48%), respectively.

Note: As shown in Table 1, values of volume for quartiles associated with hospital and independent clinical laboratories differ.

These results were consistent in multivariate analyses (Table 2). Hospital laboratories had 1.87 higher odds of possessing the capability to send results electronically compared to independent laboratories ($p < 0.001$). The largest laboratories (e.g., fourth quartile) had 4.40 higher odds of possessing the capability to send test results electronically compared to the smallest laboratories (e.g., first quartile) (OR = 3.46–5.60, $p < 0.001$). Laboratories which had a higher share of potential exchange partners within their county had significantly greater capability to send results electronically (OR = 1.01, $p < 0.05$).

Among independent laboratories, the multivariate analyses (Table 2) showed that laboratory size, as indicated by the volume of test results, was strongly associated with capability to send results electronically. Larger laboratories with higher test volumes (e.g. second to fourth quartiles) had approximately two to eight times higher odds (OR = 2.63–7.99, $p \leq 0.001$) of possessing the capability to send results electronically compared to laboratories with the lowest test volumes (e.g. first quartile). Independent laboratories affiliated with a university/academic medical center had significantly lower odds of possessing the capability to send results electronically compared to commercial laboratories (OR = 0.27, $p < 0.05$). Among independent laboratories, we found the greater share of potential exchange partners was significantly associated with electronic test result capability (OR = 1.02, $p < 0.05$).

Among hospital laboratories (Table 2), multivariate analyses showed that larger laboratories (e.g., second to fourth quartiles) had significantly higher odds of having the capability to send results electronically compared to the smallest laboratories with the lowest test volumes (e.g. first quartile) (OR = 1.78–2.57, $p \leq 0.001$). Hospital laboratories affiliated with not-for-profit hospitals had 1.35 higher odds of possessing the capability to send test results electronically compared to hospital laboratories affiliated with for-profit hospitals ($p < 0.05$). Hospital laboratories actively participating in a HIO had 1.87 higher odds of possessing the capability to send test results electronically compared to those who did not (OR = 1.22–2.87, $p < 0.01$).

3.3. Exchange activity among clinical laboratories

Nationwide, three out of ten clinical laboratories sent more than 75% of their test results electronically (Fig. 2). This rate did not vary by the size of the clinical laboratory, as measured by the volume of test results sent, nor by whether they were a hospital or an independent laboratory. In multivariate analyses conducted across all clinical laboratories

(Table 3), the share of potential exchange partners was the only factor significantly associated with higher levels of exchange activity (OR = 1.02, $p < 0.05$).

Note: As shown in Table 1, values of volume for quartiles associated with hospital and independent clinical laboratories differ.

Among independent laboratories, multivariate analyses (Table 3) showed that independent laboratories affiliated with clinic/group practice or a health system had approximately 3.33 higher odds of sending more than 75% of their test results electronically compared with commercial laboratories (OR = 1.58–7.03, $p < 0.05$).

Among hospital laboratories, multivariate analyses (Table 3) showed that hospital laboratories part of hospital systems had a 1.37 higher odds of exchanging 75% or more of their results electronically compared to those not part of a hospital system (OR = 1.07–1.75, $p < 0.05$). In addition, share of providers paid by county was also significantly associated with exchange activity (OR = 1.02, $p < 0.01$). Laboratories affiliated with not-for-profit hospitals had a 0.73 lower odds of sending 75% of their test results electronically compared to those affiliated with for-profit hospitals (OR = 0.54–0.99, $p < 0.05$).

4. Discussion

When examining variation in capability to exchange and exchange activity across clinical laboratories nationwide, we found that hospital-based clinical laboratories (71%) and larger clinical laboratories (80%) had significantly higher levels of capability compared to independent (58%) and smaller laboratories (48%), respectively. However, these types of laboratories had relatively similar levels of exchange activity, with about three in ten clinical laboratories sending 75% or more of their test results electronically. Overall, clinical laboratories located in areas with greater share of potential exchange partners, as measured by the successful participation in the Medicare and Medicaid EHR Incentive Programs had small but significantly higher rates of capability and exchange activity.

After controlling for laboratory characteristics and other area characteristics, hospital laboratories were significantly more likely than independent laboratories to have the capability to send test results electronically. Hospitals' resources, business needs, and advanced health IT infrastructure may underlie these greater capabilities. Hospital laboratories were generally larger than independent laboratories, and thus may have had more resources to devote to health IT infrastructure. Hospital systems often had laboratory systems even prior to EHRs, which may indicate that hospitals also prioritized having the capability to efficiently send laboratory results electronically within their hospital systems [27]. While no laboratories received any direct financial incentives to support interoperability, most hospitals received financial incentives from the Medicare and Medicaid EHR Incentive Programs for their successful participation; [28] this may have supported efforts to become more interoperable. However, independent laboratories would not have received this indirect financial benefit.

Larger laboratories (among both independent and hospital laboratories) were more likely to have the capability to send structured test results. Many small laboratories operate

independently and have fewer financial and staff resources than larger competitors to invest in laboratory information systems [1]. Developing interfaces to connect with EHRs, has been identified as resource intensive endeavor; for example, large commercial laboratories report using hundreds of interfaces, each unique and customized [29]. In previous analysis of these survey results that examined barriers to laboratory exchange, clinical laboratories reported that costs, lack of time and limited staff were barriers to building interfaces to EHRs [30]. Participating in HIOs would serve as a means to efficiently deliver test results to many potential recipients and obviate the need for developing such interfaces; however, one-fifth of clinical laboratories cited high subscription costs for exchange service providers (e.g. such as HIOs) as the top challenge to delivering test results in a structured format [31]. Such barriers would likely have a bigger impact on smaller, independent laboratories that have fewer resources to build interfaces with individual ambulatory care providers or participate in a health information exchange entity. Among the independent laboratories, commercial laboratories were significantly more likely to possess these capabilities compared to university based labs and other types of laboratories indicating that greater infrastructure and resources can play a role in supporting the technical capabilities to electronically exchange information [32].

Enterprise-based systems may enhance the capability of large laboratories and hospital laboratories to exchange among a group of organizations. In health care settings, enterprise-based systems of electronic exchange are typically convened by large healthcare organizations and participation is limited to a select group of noncompeting organizations that share a common business interest [33–35]. Potential mechanisms to enable interoperability and exchange might include the use of a common EHR system or a portal across the participants; such might be the case between hospital laboratories and affiliated ambulatory care providers [36]. Alternatively, commercial laboratories may create interfaces with ambulatory care providers that use different EHR systems to enable the sending of test results. Although an enterprise-based model may enable interoperability among select groups, this approach doesn’t allow a broader set of stakeholders to access and exchange these data, potentially limiting public benefits [37,38].

Despite the increased capability to enable exchange, larger laboratories and hospital laboratories were not significantly more likely to send test results electronically to an ordering practitioner’s EHR. Whereas larger laboratories may have more resources to invest in infrastructure for supporting electronic test result delivery, all laboratories likely faced similar challenges in increasing the delivery of electronic test results to providers’ EHRs. One common issue faced by all laboratories was that, as of 2012, only four in ten office-based physicians had the capability to electronically receive and incorporate laboratory test results [39]. In a prior analysis, almost one in ten laboratories reported that provider EHR systems lacked the capability to receive laboratory results [40].

Overall, a higher penetration of potential exchange partners within a clinical laboratories’ local area, as indicated by the proportion of eligible professionals who were paid by the Medicare and Medicaid EHR Incentive Programs, was associated with a small but significantly higher likelihood of capability and actually sending the test results electronically to ordering practitioners’ EHRs. This was the only factor significantly

associated with higher levels of exchange activity. With greater numbers of eligible professionals participating in this program, the demand to receive results in a structured format may have increased, which in turn may have led to increases in clinical laboratories capabilities and exchange activity.

However, the impact of a greater number of potential exchange partners within a local area differed between independent and hospital laboratories; this may reflect differences in resources and incentives to establish relationships with ambulatory care providers. Greater share of potential exchange partners was significantly associated with greater exchange activity among hospital laboratories but not among independent laboratories. For independent laboratories, eligible professionals' increased EHR adoption and ability to receive structured test results electronically may have driven increased capability to send results electronically but might not have been sufficient to support actual exchange of laboratory results, which is a potentially costly endeavor, requiring developing interfaces or participation in a HIO [19]. Unlike independent laboratories, hospital-based laboratories may be part of hospital driven efforts to support the establishment of strong relationships with ambulatory care providers. Thus, hospital-based laboratories may have been in a better position to capitalize on the presence of a greater number of exchange partners in comparison to independent laboratories. Hospitals have higher rates of exchanging clinical data with ambulatory care providers, whom they wish to establish stronger relationships with in order to control referrals [41]. Among hospital laboratories, those who were part of hospital systems were more likely to electronically send a large proportion of test results electronically; this may be related to their financial interest to take advantage of a greater numbers of potential ambulatory care exchange partners affiliated with their hospital system.

HIO participation on the part of hospitals associated with hospital laboratories was associated with greater capability to exchange but not associated with increased likelihood of electronically sending greater than 75% of laboratory results to a providers' EHR. Other analyses of hospital exchange activity have found a significant association between HIO participation and hospitals' exchange activity; however, these analyses did not examine the volume of results sent; only whether hospitals exchanged data. Thus, it may be that HIOs, such as those supported through the State Health Information Exchange Cooperative Agreement Program, enabled exchange activity but the volume of exchange activity was not widespread. We were unable to obtain HIO participation among independent laboratories, and thus could not examine the role of HIOs in facilitating exchange among independent laboratories. In 2012, in a nationwide survey, over 80% of operational HIOs reported that laboratories participated and sent data to them; however, it is unclear as to the number or types of laboratories that participated in these efforts [42].

As of 2012, although a majority of clinical laboratories possessed the capability to send structured test results to an EHR, a majority of clinical laboratories were not exchanging most of their test results electronically. A number of efforts are underway that collectively should help foster laboratory exchange and interoperability. Some key initiatives include the ONC-led *Nationwide Interoperability Roadmap*, which is working to limit variation in the use and interpretation of standards focusing on vocabulary/terminology, content/structure, transport, security, and services [15]. ONC also issued the *2015 Interoperability Standards*

Advisory, which coordinates the identification, assessment, and determination of the best available interoperability standards and implementation specifications for industry use toward specific health care purposes, including those for laboratory results exchange [43].

The U.S. Food and Drug Administration, the Centers for Disease Control and Prevention (CDC)'s Health Information Technology Team in the Division of Laboratory Systems, and the National Library of Medicine are collaborating to promote semantic interoperability of laboratory data [44,45]. Specifically, these agencies are collaborating with test system manufacturers to advance laboratory interoperability between hospitals, providers, and public health agencies. The objective of this effort is to develop guidance for laboratory test system manufacturers for requesting and publishing their own suggested code sets to support their customers. Once a process is in place for test system manufacturers, further work will be done to identify optimal routes to electronically package and deliver the mapped code sets to various health IT systems, including test system data managers, EHRs, clinical laboratory information systems, public health laboratory information management systems, and CDC's national surveillance systems. The CDC has also worked with the National Institute of Standards and Technology to ensure the certification tools for hospital laboratory results interfaces support the requirements of the federal CLIA regulations and the deemed laboratory accrediting agencies [46]. The 2014 version of the Lab Results Interface certification tool includes the seven test report elements specified for ONC certification and the 2017 LRI certification tool incorporates seven of eight additional elements required by CLIA and the laboratory accreditors as voluntary elements in the certification tool.

4.1. Limitations

This survey was conducted in 2013, reflecting clinical laboratories' exchange capability and activity as of 2012. Although clinical laboratories exchange capabilities and activity may have evolved since this time, the goal of this analysis was to identify factors associated with capability and exchange activity which are critical to developing a national strategy to enable greater laboratory interoperability, and this is the only known national data source on laboratory exchange capability and activity. Additionally, the analysis uses a self-reported data which are subject to measurement error that could bias results; those who responded may be more likely to engage in laboratory exchange potentially resulting in an overestimate of laboratory exchange capability and activity.

5. Conclusion

In summary, as of 2012, hospital-based clinical laboratories and larger clinical laboratories had significantly higher levels of capability compared to independent and smaller labs, respectively. Differences in exchange capability between independent and hospital laboratories, and between larger and smaller laboratories, suggests the need for tailored approaches to drive greater interoperability that address the varying drivers of interoperability and differing resources of laboratories. However, all laboratories regardless of size or type had similarly low levels of exchange activity, also suggesting laboratories face some common issues that impede interoperability as well. Clinical laboratories located in areas with a greater share of providers paid by the Medicare and Medicaid EHR Incentive

Programs had a small but significantly higher likelihood of possessing capability to exchange and engaging in exchange activity. Given the critical role that clinical laboratories play in clinical care and generating efficiency benefits of HIE, it will be important to repeat this survey in the future to assess changes in clinical laboratories' exchange activity.

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Summary point

What is currently known on this topic:

- Increasing interoperability of laboratory data—the electronic capture, storing, and transmitting of test results in structured formats—may improve the timely delivery of test results to health care providers, leading to efficiencies such as reductions in duplicate test ordering and enhancements to patient safety and quality of care by alerting providers of abnormal test results.
- Based upon an earlier analysis of an ONC national survey of clinical laboratories conducted in 2013, about 6 in 10 possessed the capability to send structured test results electronically, and less than half (3 in 10 overall) sent more than three-quarters of their test results as structured data to ordering practitioners' EHR systems. However, it is unknown as to how interoperability varies across clinical laboratories.

This paper is the first study to examine factors associated with clinical laboratories' electronic capability and exchange of clinical test results of an ONC national survey of clinical laboratories conducted in 2013. The contribution of this study includes:

- When examining variation in capability to exchange across clinical laboratories nationwide, we found that hospital-based clinical laboratories (71%) and larger clinical laboratories (80%) had significantly higher levels of capability compared to independent (58%) and smaller labs (48%), respectively.
- However, different types of laboratories had relatively similarly low levels of exchange activity, with about three in ten clinical laboratories sending 75% or more of their test results electronically.
- We found that clinical laboratories located in areas with greater share of potential exchange partners, as measured by the successful participation in the CMS Medicare and Medicaid EHR Incentive Programs had small but significantly higher rates of capability and exchange activity.

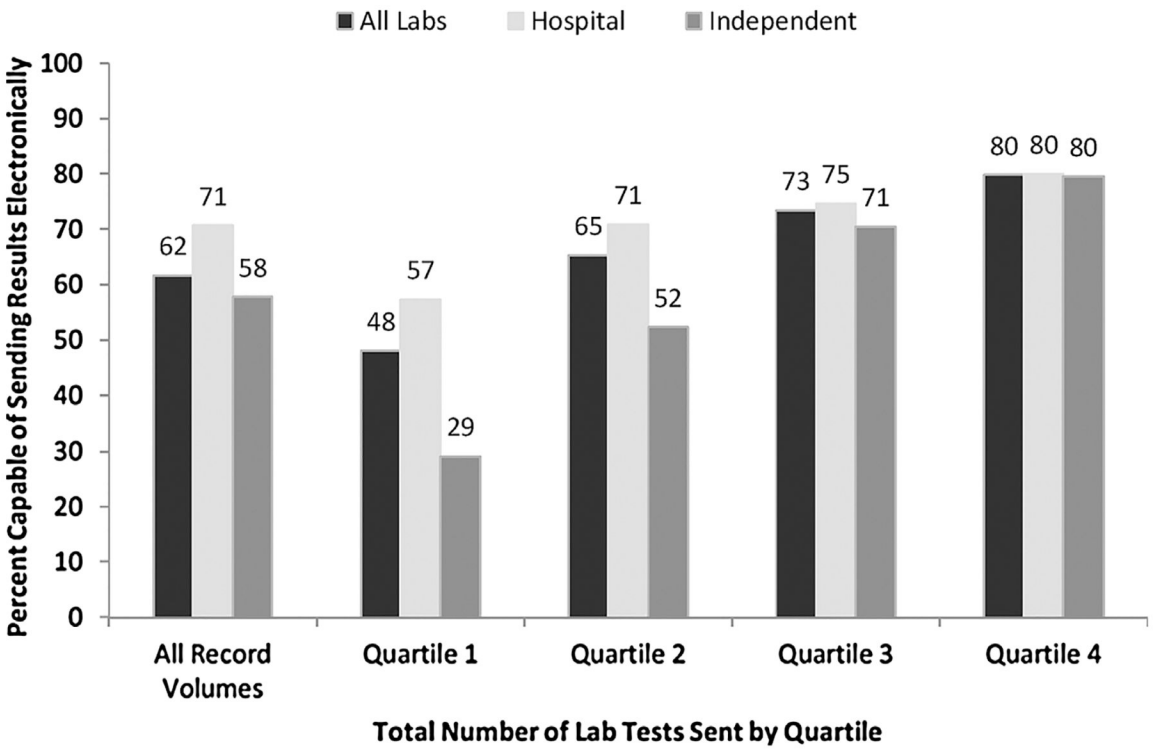

Fig. 1.
Clinical Laboratories' Capability of Sending Results Electronically.

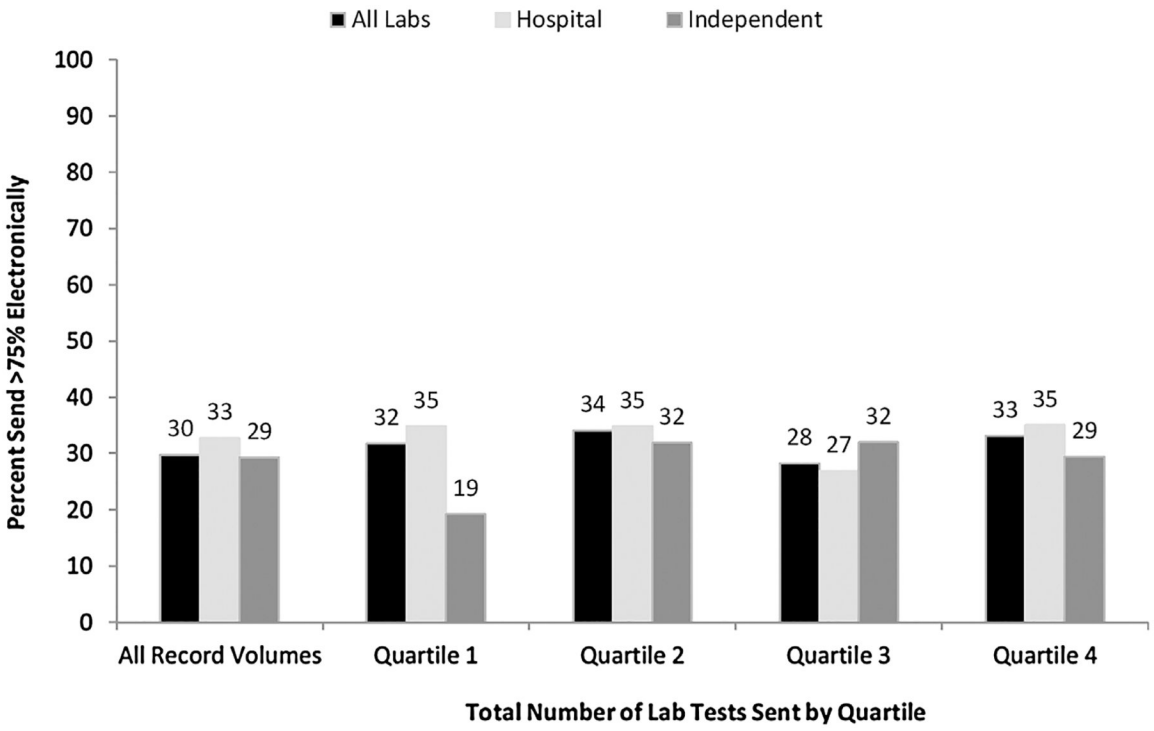

Fig. 2.
Percent of Clinical Laboratories that Send More than 75% of Test Results Electronically.

Table 1

Characteristics of Clinical Laboratories Nationwide.

Overall Characteristics, n (weighted)= 9382	**%**
Lab type (%)	
Independent Laboratory	32
Hospital Laboratory	68
Area characteristics	
Metropolitan Statistical Areas (%)	
Large Cities	71
Rural Areas	15
Small Cities / Micropolitan Areas	14
Mean share of eligible professionals paid by county for CMS EHR Incentive Program (Stage 1 Meaningful Use)	23
Characteristics of Independent Laboratories, n(weighted) = 2,874	
Lab size (volume of records sent electronically) by Quartile	
1st quartile	0–5,770
2nd quartile	5,771 – 25,558
3rd quartile	25,559 – 143,049
4th quartile	143,050 and up
Type of Laboratory (%)	
Commercial laboratory	47
University/academic center	7
Clinic or group practice	22
Health system	7
Other laboratory type	17
Characteristics of Hospital Laboratories, n(weighted) = 6,082	
Lab size (volume of records sent electronically) by Quartile	
1st quartile	0 – 57,975
2nd quartile	57,976–210,604
3rd quartile	210,605–751,057
4th quartile	751,058 and up
Organizational characteristics	
Hospital is a non-federal organization (%)	30
Hospital is a not-for-profit organization (%)	53
System Membership (%)	55
HMO product offed by hospital/system (%)	12
Area Characteristics	
Low level of market concentration (HHI)	49
Adoption of Health IT and HIE services	
Active HIE Participation (%)	18
Basic EHR Adoption (%)	29
Basic EHR Adoption and Active HIO Participation (%)	10

Source: National Survey on Health Information Exchange in Clinical Laboratories.

Table 2

Logistic Regression Results: Probability a laboratory is capable of sending results electronically.

	Odds Ratio	OR Lower CI	OR Upper CI	p-Value
Clinical Laboratories (combined sample)				
Intercept	0.69	0.57	0.85	0.000
Lab Size (volume of test results sent electronically by Quartile)				
Number of records sent, 1st quartile (REF.)	---	---	---	---
Number of records sent, 2nd quartile	2.05	1.64	2.55	<.0001
Number of records sent, 3rd quartile	3.00	2.31	3.90	<0001
Number of records sent, 4th quartile	4.40	3.46	5.60	<0001
Laboratory Type				
Hospital Laboratory (vs. Independent)	1.87	1.54	2.28	<.0001
Area characteristics				
Metropolitan Statistical Areas				
Large Cities / Metropolitan Areas (REF.)	---	---	---	---
Rural Areas	1.11	0.87	1.43	0.402
Small Cities / Micropolitan Areas	0.97	0.74	1.28	0.852
Mean share of eligible professionals paid by county for CMS EHR Incentive Program (Stage 1 Meaningful Use)	1.01	1.00	1.02	0.009
Independent Labs	**Odds Ratio**	**OR Lower CI**	**OR Upper CI**	**p-Value**
Intercept	0.35	0.20	0.60	0.000
Lab Size (volume of test results sent electronically by Quartile)				
Number of records sent, 1st quartile (REF.)	---	---	---	---
Number of records sent, 2nd quartile	2.63	1.55	4.45	0.001
Number of records sent, 3rd quartile	6.19	3.98	9.62	<.0001
Number of records sent, 4th quartile	7.99	5.09	12.53	<.0001
Organizational Characteristics				
Organizational affiliation: commercial laboratory (REF.)	---	---	---	---
Organizational affiliation: university/academic center	0.27	0.13	0.56	0.000
Organizational affiliation: clinic or group practice	0.75	0.50	1.12	0.160
Organizational affiliation: health system	0.93	0.48	1.80	0.829
Organizational affiliation: other laboratory type	0.42	0.27	0.64	<.0001
Area characteristics				
Metropolitan Statistical Areas				
Large Cities / Metropolitan Areas (REF.)	---	---	---	---
Rural Areas	1.47	0.43	5.01	0.540
Small Cities / Micropolitan Areas	0.91	0.51	1.62	0.742
Mean share of eligible professionals paid by county for CMS EHR Incentive Program (Stage 1 Meaningful Use)	1.02	1.00	1.04	0.033
Hospital Labs	**Odds Ratio**	**OR Lower CI**	**OR Upper CI**	**p-Value**
Intercept	0.93	0.64	1.36	0.717
Lab Size (volume of test results sent electronically by Quartile)				
Number of records sent, 1st quartile (REF.)	---	---	---	---

Number of records sent, 2nd quartile	1.78	1.35	2.33	<.0001
Number of records sent, 3rd quartile	2.15	1.50	3.07	0.000
Number of records sent, 4th quartile	2.57	1.89	3.48	<0001
Organizational characteristics				
Hospital is a non-federal organization (vs. not)	1.02	0.75	1.39	0.898
Hospital is a not-for-profit organization (vs. not)	1.35	1.06	1.72	0.017
System Membership (vs. not)	1.16	0.92	1.45	0.209
HMO product offered by hospital (vs. not)	1.36	0.98	1.90	0.068
Area characteristics				
Metropolitan Statistical Areas				
Large Cities / Metropolitan Areas (REF.)	---	---	---	---
Rural Areas	1.07	0.81	1.41	0.641
Small Cities / Micropolitan Areas	1.01	0.74	1.38	0.954
Market concentration (HHI) - High (vs. low)	0.81	0.65	1.02	0.067
Mean share of eligible professionals paid by county for CMS EHR Incentive Program (Stage 1 Meaningful Use)	1.00	1.00	1.01	0.478
Adoption of Health IT and HIE services				
Active HIO Participation (vs. not)	1.87	1.22	2.87	0.004
Basic EHR Adoption (vs. not)	1.26	0.94	1.70	0.122
Basic EHR Adoption and Active HIE Participation (vs. not)	0.87	0.46	1.66	0.678

Source: Authors' calculations using National Survey on Health Information Exchange in Clinical Laboratories.

Table 3

Logistic regression for the probability that a laboratory will send greater than 75% of lab results electronically.

	Odds Ratio	OR Lower CI	OR Upper CI	p-Value
Clinical Laboratories (combined sample)				
Intercept	0.27	0.18	0.39	<.0001
Lab Size (volume of test results sent electronically by Quartile)				
Number of records sent, 1st quartile (REF.)	---	---	---	---
Number of records sent, 2nd quartile	1.15	0.73	1.81	0.513
Number of records sent, 3rd quartile	0.85	0.64	1.14	0.286
Number of records sent, 4th quartile	1.03	0.76	1.40	0.835
Laboratory Type				
Hospital Laboratory (vs. Independent)	1.30	0.80	2.09	0.238
Area Characteristics				
Metropolitan Statistical Areas				
Large Cities / Metropolitan Areas (REF.)	---	---	---	---
Rural Areas	0.98	0.74	1.32	0.912
Small Cities / Micropolitan Areas	0.73	0.52	1.03	0.075
Mean share of eligible professionals paid by county for CMS EHR Incentive Program (Stage 1 Meaningful Use)	1.02	1.01	1.03	0.000
Independent Labs	**Odds Ratio**	**OR Lower CI**	**OR Upper CI**	**p-Value**
Intercept	0.10	0.03	0.34	0.001
Lab Size (volume of test results sent electronically by Quartile)				
Number of records sent, 1st quartile (REF.)	---	---	---	---
Number of records sent, 2nd quartile	1.84	0.35	9.64	0.424
Number of records sent, 3rd quartile	1.93	0.79	4.75	0.143
Number of records sent, 4th quartile	1.70	0.78	3.71	0.179
Organizational Characteristics				
Organizational affiliation: commercial laboratory (REF.)	---	---	---	---
Organizational affiliation: university/academic center	1.54	0.30	8.05	0.579
Organizational affiliation: clinic or group practice	2.92	1.33	6.45	0.011
Organizational affiliation: health system	3.33	1.58	7.03	0.002
Organizational affiliation: other laboratory type	0.68	0.25	1.88	0.440
Area Characteristics				
Metropolitan Statistical Areas				
Large Cities / Metropolitan Areas (REF.)	---	---	---	---
Rural Areas	0.14	0.01	4.08	0.230
Small Cities / Micropolitan Areas	1.09	0.47	2.53	0.831
Mean share of eligible professionals paid by county for CMS EHR Incentive Program (Stage 1 Meaningful Use)	1.02	0.98	1.07	0.293
Hospital Labs	**Odds Ratio**	**OR Lower CI**	**OR Upper CI**	**p-Value**
Intercept	0.37	0.23	0.58	<.0001
Lab Size (volume of test results sent electronically by Quartile)				
Number of records sent, 1st quartile (REF.)	---	---	---	---

Number of records sent, 2nd quartile	1.00	0.71	1.42	0.991
Number of records sent, 3rd quartile	0.61	0.43	0.86	0.005
Number of records sent, 4th quartile	0.81	0.58	1.13	0.211
Organizational Characteristics				
Hospital is a non-federal organization	0.75	0.47	1.22	0.221
Hospital is a not-for-profit organization	0.73	0.54	0.99	0.040
System Membership (vs. not)	1.37	1.07	1.75	0.012
HMO product offered by hospital (vs. not)	1.39	0.99	1.94	0.056
Area Characteristics				
Metropolitan Statistical Areas				
Large Cities / Metropolitan Areas (REF.)	---	---	---	---
Rural Areas	1.16	0.84	1.60	0.363
Small Cities / Micropolitan Areas	0.76	0.55	1.05	0.097
Market concentration (HHI) - High (vs. low)	1.07	0.79	1.45	0.628
Mean share of eligible professionals paid by county for CMS EHR Incentive Program (Stage 1 Meaningful Use)	1.02	1.01	1.02	0.002
Adoption of Health IT and HIE services				
Active HIO Participation (vs. not)	1.06	0.62	1.80	0.834
Basic EHR Adoption (vs. not)	1.22	0.85	1.74	0.268
Basic EHR Adoption and Active HIO Participation (vs. not)	1.40	0.67	2.91	0.355

Source: National Survey on Health Information Exchange in Clinical Laboratories