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Pending Laboratory Test Results at the Time of Discharge: A 3-Year Retrospective Comparison of Paper Versus Electronic Test Ordering in Three Emergency Departments

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Abstract. Pending laboratory test results at discharge can have major adverse health outcomes. The availability of test results at discharge may depend on whether the tests were ordered electronically or by using a paper-based system. The aim of this study was to determine the rate of pending test results at time of discharge from Emergency Departments (ED), and compare the rate for paper-based and electronic orders across three EDs in New South Wales, Australia. This retrospective study described 71,466 ED presentations with 357,476 laboratory tests across three years (2014-2016). Only patients who were treated in ED and eventually discharged from ED were included. Most tests were ordered using the electronic system (97.2%, n=347,469). The rate of pending test results was significantly lower for electronic orders (6.6%, n= 22,928) than for paper orders (9.7%, n=966): a difference of 3.1%. Similar differences were observed when analysis was done by year of ED presentation. Moreover, in a subgroup analysis that included the top five high volume tests, four of the five tests had significantly lower rates of pending test results for electronic orders than for paper-based orders. The study highlighted an important benefit of ordering tests via electronic system which can potentially improve patient outcomes.

Keywords. Pending test results, emergency department, order type, electronic ordering, paper order

Introduction

Laboratory tests are one of the main tools used in clinical-decision making[1]. In Emergency Departments (EDs), ideally, a test result should be available as early as possible and prior to patient discharge to allow timely and effective use of test results in decision-making for treatment and management. However, evidence from systematic reviews has suggested that up to 75% of test results are not available before patient

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discharge from hospital[2, 3]. Results of tests ordered while patients are in hospital which are not available by the time of patient discharge are called pending test results [2].

Pending laboratory test results can have major health consequences[4]. Pending test results at discharge are less likely to be followed-up and may lead to missed or delayed diagnosis, increased hospital presentations, adverse drug reactions and sub-optimal patient outcomes[3, 5].

Electronic Medical Records (EMR) have become an integral part of patient care in many Australian hospitals[6], incorporating computerised provider order entry systems which allow clinicians to order tests and receive results electronically. Although EMR may be available to clinicians, paper-based test ordering is still prevalent. One of the benefits of electronic systems is that they provide a platform to streamline laboratory workflow [7] which may lead to improved test result availability before patient discharge. Whereas, paper-based systems can be more time-consuming to process within the laboratory and therefore may delay test result availability.

To date, studies assessing the relationship between test order types (paper-based or electronic) and the rate of pending test results at patient discharge from ED are lacking. Therefore, using a 3-year linked dataset across three New South Wales (NSW) hospitals, this study aimed to determine the rate of pending test results at time of discharge from ED, and compare the rate for paper-based and electronic orders. We hypothesised that tests ordered electronically would be less likely to be pending at discharge compared to those ordered using paper-based processes.

1. Methods

1.1. Setting

The retrospective study was conducted across three hospital EDs in NSW, Australia: one large metropolitan hospital with over 500 beds [Hospital A] and two smaller regional hospitals [Hospital B and C]. The project was part of a partnership project funded by National Health and Medical Research Council of Australia Partnership Grant (APP1111925) in partnership with NSW Health Pathology, and Australian Commission on Safety and Quality in Healthcare [8]. All three hospitals had on-site laboratories and were serviced by one pathology laboratory provider. The EMR (Cerner PowerChart system) was introduced across study hospitals in 2009, initially using Version 2007.16, and upgraded to Version 2010.02.16 in May 2011. The Laboratory Information System (LIS) was initially based on the Integrated Software Solutions (ISS) Omnilab v9.4.2 SR10 system and upgraded in October 2015 to Omnilab v11.1 SR23.

Ethics approval was granted by the Human Research Ethics Committee of the South Eastern Sydney Local Health District (HREC/16/POWH/412) and ratified by Macquarie University.

1.2. Dataset

We linked LIS and ED datasets for all patients attending the study EDs between January 2014 and December 2016. Detailed information on the contents of the ED and LIS datasets and the linkage process have been described elsewhere [9, 10].

This study included patients who were treated and discharged from ED with at least one pathology test ordered. Furthermore, only clinical chemistry and haematology tests

were selected as these were the most commonly ordered tests in our study EDs. Our analyses excluded point of care tests, add-on tests, and tests that are closely related to each other (e.g. as Automated Differential and Full Blood Count are conducted together using the same analyser, we included only Automated Differential in this analysis). Point of care tests which are performed at the bedside, (e.g. arterial blood gas) were excluded from this analysis as their results are normally available while patients are in care. An add-on is an additional test that is carried out on a specimen that has already been delivered to the laboratory. Add-ons were excluded as the process of add-on testing does not follow the same process as a new test order[11].

1.3. Statistical Analysis

Descriptive statistics including median with inter-quartile range (IQR) for continuous variables and frequency with percentages (%) and 95% confidence interval (CI) for categorical data were reported. Test sets [e.g. EUC, Electrolyte, Urea, Creatinine) were treated as single tests. A *pending laboratory test result* was defined as the unavailability of a verified test result at the time of patient discharge from the ED. The rates of pending test results for paper-based orders and electronic orders were compared and statistical tests were conducted using Pearson's Chi-squared test. As a subgroup analysis, the top five most frequently ordered tests were selected and the rate of pending test results for paper-based orders and electronic orders were compared. Data linkage was performed using SAS version 9.4. Analyses were conducted using Stata version 15.

2. Results

2.1. Paper-based and Electronic Test Ordering

During the three-year study period (2014-2016), there were a total of 71,466 ED presentations (n=50,613 patients) with 357,476 clinical chemistry and haematology tests in the final linked dataset. From these, 72.6% (n=259,709) were clinical chemistry and 27.4% (n=97,767) were haematology tests. Overall, there were 10,007 (2.8%) paper-based and 347,469 (97.2%) electronic test orders. The rate of paper-based test orders were roughly the same for clinical chemistry (2.8%) and haematology (2.9%).

2.2. Demographic and ED Visit Characteristics

Of the total 71,466 ED presentations, 55.9% were female and the median (IQR) age was 49 (30-69) years. Most of the ED presentations occurred at Hospital A (38.7%) while presentations to Hospital B and C were roughly the same (30.5% each). The rates of paper-based orders were the same for both genders (2.8% each) but slightly varied by age group and study hospital.

2.3. Rate of Pending Test Results

Table 1 presents the rate of pending test results by order types. The rate of pending test results at discharge was lower for electronic orders than for paper-based orders for all

hospitals. The overall rate of pending test results was 6.6% for electronic orders and 9.7% for paper-based orders: a statistically significant difference of 3.1% (*P<0.001*) (Table 1).

Table 1. Rate of pending test results at ED discharge by hospitals and order types, 2014-2016. *P<0.001 versus electronic order types; CI, Confidence Interval.

Hospital	Test order type	Test Count	Pending Test Result	
			Test Count	% (95% CI)
Hospital A	Paper	3,746	418	11.2 (10.2-12.2) *
	Electronic	117,025	9,632	8.2 (8.1-8.4)
Hospital B	Paper	2,710	237	8.7 (7.7-9.9) *
	Electronic	97,949	5,220	5.3 (5.2-5.5)
Hospital C	Paper	3,551	311	8.8 (7.8-9.7) *
	Electronic	132,495	8,076	6.1 (6.0-6.2)
Overall	Paper	10,007	966	9.7 (9.1-10.2) *
	Electronic	347,469	22,928	6.6 (6.5-6.7)

Figure 1 shows the rate of pending test results by order types over three years (2014-2016). The rate of pending test results was consistently and significantly lower for electronic orders than for paper-based orders (*P<0.001*). While the rate of pending test results did not change considerably over time for paper-based orders, for electronic orders the rate dropped from 8.0% in 2014 to 5.4% in 2016.

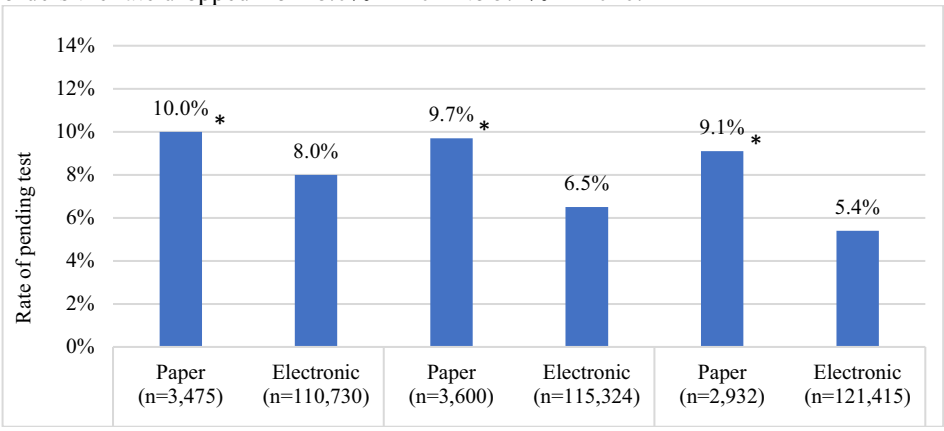

Figure 1. Rate of pending test results at ED discharge by order types overtime, all hospitals combined, 2014-2016. **P<0.001* versus electronic orders.

2.4. Rate of Pending Test Results for Top Five Tests

As a subgroup analysis, the top five high volume tests [Automated Differential, EUC, Liver Function Test (LFT), Calcium Magnesium Phosphate (CaMgPO4) and C-Reactive Protein (CRP)] were selected. These tests represented 70% (n= 250,785) of the total tests included in the study. Four of the five tests had significantly lower rates of pending test results for electronic orders than for paper-based orders (Table 2).

Table 2. Rate of pending test results at ED discharge for the top five tests, by type of test order, all hospitals combined, 2014-2016. *P<0.05 *versus* electronic order; #non-significant versus electronic order; EUC, Electrolyte, Urea, Creatinine; LFT, Liver Function Test; CaMgP04, Calcium Magnesium Phosphate; CRP, C-Reactive Protein.

Test	Test order type	Test Count	Pending Test Result	
			Test Count	% (95% CI)
Automated Differential	Paper	993	185	18.6 (16.3-21.2) *
	Electronic	69,540	10,175	14.6 (14.4-14.9)
EUC	Paper	1,052	73	6.9 (5.5-8.6) *
	Electronic	68,916	2,589	3.8 (3.6-3.9)
LFT	Paper	1,009	52	5.2 (3.9-6.7) *
	Electronic	45,021	1,512	3.4 (3.2-3.5)
CaMgP04	Paper	642	33	5.1 (3.6-7.1) *
	Electronic	33,545	959	2.9 (2.7-33.0)
CRP	Paper	964	42	4.4 (3.2-5.8) #
	Electronic	29,103	1,165	4.0 (3.8-4.2)

3. Discussion

This study examined the relationship between test order types (paper or electronic) and the rate of pending test results at the time of discharge from EDs across three hospitals in Australia. The major finding is that the rate of pending test results was significantly lower for electronic orders (6.6%) than for paper orders (9.7%). Similar significant differences were observed when analysis was done by year of ED presentation (Figure 1). These findings support our original hypothesis that electronically ordered tests are less likely to be pending at discharge compared to paper ordering.

Possible explanations for the lower rate of pending test results with electronic orders could be related to the improved timeliness of laboratory workflow when the electronic system is used[12-14]. Earlier studies have reported improvement in overall turnaround time (TAT) with electronic systems, including shorter *data entry time* [i.e. the time from a specimen arrival in the central specimen reception area of the laboratory to when it is forwarded on for processing][12] and *overall* TAT [i.e. the time of clinician request to the issue of a laboratory result][13]. For example, Georgiou *et al.* found that the median *data entry time* was 3 minutes shorter for electronic orders than paper orders [12]. In a study by Thompson et al. following the implementation of electronic system, the median time from the order of a test to obtaining specimens decreased from 77 to 21.5 minutes while the *overall* TAT decreased from a median of 148 to 74 minutes [13].

The important clinical implication of the study is that electronic ordering system has the capacity to improve patient safety. Pending tests are a risk factor for the failure to follow-up test results which can be a major source of harm for patients[3-5]. Lower rates of pending test results with electronic ordering, as observed in this study, could lead to a reduction in potentially harmful outcomes that may arise from abnormal laboratory results arriving after patient discharge [5].

The focus of this study was on test order type and our interpretation is limited by a lack of information on the nature of the results and relevant follow up actions (such as abnormal result returned post discharge), and the exclusion of certain test types. Information on results of pending test results were not included in this study. Therefore, we did not assess whether the results of the pending test results were potentially actionable. We included only clinical chemistry and haematology tests in the current analysis. Other tests such as microbiology, immunology and endocrinology were not

included and the impact of the electronic system on the availability of results of these tests may be different from our current findings. Paper ordering has remained consistent at around 2-3% over the course of this study. Further research into this area should explore why paper systems continue to be used.

In conclusion, to the best of our knowledge, this is the first study on the relationship between test order type and the rate of pending test results at ED discharge. Our findings highlighted an important benefit of ordering tests via the electronic system which can potentially improve patient safety. Future research is needed to explore how pending test results are managed, including how abnormal test results arriving after discharge from ED are communicated to clinicians and patients.

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