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Ordering Patterns and Costs of Specialized Laboratory Testing by Hospitalists and House Staff in Hospitalized Patients With HIV at a County Hospital: An Opportunity for Diagnostic Stewardship

Kathryn Bolles,[1] **Laila Woc-Colburn,**[2] **Richard J. Hamill,**[2,3] **and Vagish Hemmige**[4]

[1]Department of Medicine, University of Washington, Seattle, Washington; [2]Division of Infectious Diseases, Department of Medicine, Baylor College of Medicine, Houston, Texas; [3]Medical Care Line, Section of Infectious Diseases, Michael E. DeBakey Veterans Affairs Medical Center, Houston, Texas; [4]Division of Infectious Diseases, Montefiore Medical Center, Bronx, New York

Background. Inpatient HIV care often requires specialized laboratory testing with which practitioners may not be familiar. In addition, computerized physician order entry allows for ordering tests without understanding test indications, but it can also provide a venue for education and diagnostic stewardship.

Methods. All charts of HIV-positive patients hospitalized at a tertiary care public safety net hospital in Houston, Texas, between January 1, 2014, and June 30, 2014, were reviewed for a set list of laboratory tests. Appropriateness of test ordering was assessed by 2 providers. Cost estimates for each test were obtained from Medicaid and a national nonprofit health care charge database.

Results. A total of 274 HIV-positive patients were admitted 429 times in the 6-month study period. During the study period, 45% of the study laboratory tests ordered were not indicated. A total of 532 hepatitis serologies were ordered, only 52% of which were indicated. Overall, 71 serum qualitative cytomegalovirus (CMV) polymerase chain reactions (PCRs) and eight CMV quantitative PCRs were ordered, with most (85%) qualitative PCRs ordered for nonspecific signs of infection (eg, fever). Other tests ordered without clear indications included *Aspergillus* IgE (7), serum Epstein-Barr virus (EBV) PCR (5), parvovirus serology (7), and *Toxoplasma* IgM (18). Overall, the estimated laboratory cost of inappropriate testing over the study period was between $14 000 and $92 000, depending on which cost database was used.

Conclusions. Many tests ordered in HIV-positive inpatients do not have indications, representing a substantial source of health care waste and cost and potentially leading to inappropriate treatment. Opportunities exist to decrease waste through education of trainees and hospitalists and through implementation of diagnostic stewardship via the electronic medical record.

Keywords. CPOE; diagnostic stewardship; EMR; health care expenditures; HIV; test ordering.

The advent of highly active antiretroviral therapy (HAART) has changed the nature of HIV infection. The number of hospitalizations for HIV subjects without concurrent infection with hepatitis C in the National Inpatient Discharge Survey decreased from 29.8 per 100 person-years in 1996 to 5.3 per 100 person-years in 2010 [1]. However, urban safety net hospitals continue to care for large numbers of HIV-infected patients despite the availability of HAART [2]. As hospitalizations for HIV decrease, few hospitals still maintain dedicated HIV inpatient services, and the primary caregiver for patients hospitalized with HIV will typically be a hospitalist or other generalist physician, who may not see the volume of patients necessary to maintain expertise in HIV care [3].

Patients with advanced AIDS due to untreated HIV infection are at risk for a large number of bacterial, fungal, mycobacterial, viral, and parasitic infections, as well as malignant processes. Consequently, the differential of an infectious syndrome in a patient with advanced AIDS is broad and includes entities rarely seen in healthier patients [4]. As a result, the infectious workup in this population includes a number of tests that generalist providers do not frequently order. Infrequently ordered tests have been shown to demonstrate the greatest variability in provider-to-provider use and the greatest overuse [5, 6].

Inappropriately ordered tests, in addition to the financial toxicity and waste associated with the test itself, may prompt inappropriate pharmacotherapy if improperly interpreted. Accordingly, diagnostic stewardship has increasingly been recognized as a critical component of antimicrobial stewardship [7].

Computerized physician order entry (CPOE) via the electronic medical record (EMR) has been widely adopted in health care institutions in recent years with the goal of improving efficiency and decreasing waste [8]. However, some providers at our institution informally noted that CPOE occasionally led to front-line providers ordering large numbers of tests with which they were unfamiliar and which they likely would not have ordered had they not appeared in the CPOE's database of orderable tests, a phenomenon that was dubbed "button clicking syndrome." Although some early studies have suggested that introduction of CPOE did not significantly change utilization of basic lab tests [9, 10], multiple subsequent studies have suggested that electronic medical records may in fact increase the rate of lab and diagnostic imaging utilization [11, 12]. However, literature on ordering behavior of less commonly ordered tests in the CPOE era is lacking.

Although a large number of studies have looked at ways to reduce the laboratory costs of commonly ordered tests in inpatient and outpatient settings by reducing laboratory waste, no study has examined the use of specialized testing in the hospitalized HIV population [13]. Accordingly, we set out to examine the use of specialized infectious diseases–related testing in the HIV population in the setting of CPOE to identify targets for diagnostic stewardship.

METHODS

All patients hospitalized with HIV at Ben Taub Hospital, a tertiary care public safety net hospital in Houston, Texas, between January 1, 2014, and June 30, 2014, were identified from a database generated as part of a separate, unrelated prospective trial of inpatients with HIV. Patients were identified as potentially eligible for that study by daily audit of the inpatient census using EMR reports. Patients were admitted to either housestaff or hospitalist services. A dedicated HIV consult service was available. Hospital policy required teams to notify the HIV service of all HIV-infected patients admitted to the hospital; however, there was no enforcement of the notification requirement at the time of the study. The HIV service primarily functioned as a true consult service, but it occasionally ordered restricted medications (eg, antiretrovirals) or laboratory tests (eg, HIV genotype) on behalf of primary services.

All patients' charts were reviewed by 2 providers for a set list of laboratory tests evaluating for fungal, mycobacterial, viral, and parasitic diseases excluding routine testing (eg, blood cultures, urine cultures, CD4 count, HIV viral load). Assessment for appropriateness was made by each provider according to specific criteria (Table 1), which were developed by the study team specifically for inpatient HIV populations. The criteria were developed for this study and sought to avoid tests that would either rarely or invariably be positive, would not yield meaningful diagnoses, or would not change clinical management. Differences between providers in assessment of appropriateness were mediated by consensus. Date ordered, ordering service, and level of training of the ordering provider for the tests in Table 1 were recorded, as was whether the infectious diseases (ID) consult service had recommended the test in their consult note.

Two cost estimates were obtained for each laboratory test: the Texas Medicaid 2014 reimbursement [14] and the price obtained by searching the FAIR Health nonprofit health care charge database (search parameters: ZIP code 77030, uninsured patient, 80th percentile of database costs) [15]. The latter was chosen due to its use in both Agency for Healthcare Research and Quality materials [16] and state law in many states [17]. Medicaid reimbursement alone was not used, as Medicaid reimbursements are typically below cost.

Standard descriptive statistics and differences in proportions between groups were calculated, and statistical significance was assessed by χ^2 testing as appropriate. All statistical analysis was performed in Stata 12.0 (Statacorp, College Station, TX).

This study was carried out as part of a quality improvement project to decrease inappropriate test ordering in HIV-infected hospitalized patients; accordingly, it was exempt from institutional review board review.

RESULTS

In the 6-month study period, 274 HIV-positive patients were admitted 429 times. Although 191 (69.7%) patients were only admitted once, for a median of 1 admission per patient, the interquartile range was 1–3 admissions, and the total range was 1–10 admissions. Of these 274 patients, 170 (62.0%) had been previously admitted to the hospital system in the decade before the study period, and only 14 (5.1%) had a new diagnosis of HIV.

Overall, a total of 1010 study tests were ordered: 560 by housestaff services, 278 by hospitalist services, 109 by intensive care services, 30 by surgical services, 20 by obstetrics and gynecology, and 13 by other services (ie, emergency medicine, neurology, psychiatry) (Table 2). Tests were predominantly ordered by the primary team residents (452 tests, 44.8% of total ordered) or attendings (323, 32.0%). During the study period, the most commonly ordered study tests were hepatitis serologies (52.7% of all tests performed), *Toxoplasma* serologies (10.4%), cytomegalovirus (CMV) polymerase chain reactions (PCRs; 9.4%), and non-herpes simplex virus, non-CMV PCRs (11.2%). Of study laboratory tests ordered, only 55% were indicated (Figure 1), which improved but did not resolve with infectious diseases/HIV team consultation—13% of ID-recommended tests were also not indicated by our study criteria. We observed that 216/1010 (21.4%) tests were ordered the day of admission, with 196 (19.4%) and 201 (19.9%) tests ordered on each of the

Table 1. Laboratory Tests Catalogued for This Study, With Appropriateness Criteria

Test	Indication in Inpatients With HIV	Total Tests Ordered	Appropriate
Adenovirus Ab	None	1	0 (0%)
Aspergillus IgE	Evaluation for allergic bronchopulmonary aspergillosis	7	0 (0%)
Aspergillus Ag	Suspicion for invasive aspergillosis in appropriate host (hematologic malignancy or transplant)	8	1 (12.5%)
Bartonella Ab	Suspected peliosis or bacillary angiomatosis	4	3 (75.0%)
CMV IgG	Unknown CMV serostatus	40	31 (77.5%)
CMV IgM	None	19	0 (0%)
CMV PCR (CSF)	Suspected CMV encephalitis	14	13 (92.9%)
CMV PCR (BAL)	Suspected CMV pneumonitis (interstitial pattern on imaging)	1	1 (100%)
CMV PCR (serum qualitative)	Evaluation of state of disease if known end organ dz[a]	71	11 (15.5%)
CMV PCR (serum quantitative)	Evaluation of state of disease if known end organ dz[a]	8	5 (62.5%)
CMV PCR (urine)	None	1	0 (0%)
EBV IgG	None	1	0 (0%)
EBV IgM	None	1	0 (0%)
EBV PCR (CSF)	Suspected CNS lymphoma	16	15 (93.8%)
EBV PCR (serum)	Suspected post-transplant lymphoproliferative disorder after transplant	5	0 (0%)
Enterovirus PCR (CSF)	Suspected acute viral meningitis	1	1 (100%)
Hepatitis A IgG	Unknown prior serostatus	24	20 (83.3%)
Hepatitis A IgM	Acute LFT abnormality in nonimmune patient	102	25 (24.5%)
Hepatitis B core IgG	Acute LFT abnormality in nonimmune patient	5	5 (100%)
Hepatitis B core IgM	Acute LFT abnormality in nonimmune patient	109	26 (23.9%)
Hepatitis B core total	Acute LFT abnormality in nonimmune patient	25	20 (80.0%)
Hepatitis B PCR	Evaluation of status of patient with known hepatitis B	7	6 (85.7%)
Hepatitis B surface Ab	Patient with unknown immune status to hepatitis B	37	30 (81.1%)
Hepatitis B surface Ag	No prior testing or new transaminitis; dialysis screening	126	89 (70.6%)
Hepatitis C IgG	No testing in prior year or new transaminitis	104	61 (58.7%)
Hepatitis C PCR	Confirmation of positive HCV IGG	21	13 (61.9%)
Hepatitis C genotype	Patient candidate for hepatitis C therapy	6	0 (0%)
HIV Genosure (INSTI resistance)	Virologic failure in patient taking INSTIs	17	1 (5.9%)
HSV PCR (CSF)	Suspected viral meningitis	41	36 (87.8%)
HSV PCR (swab)	Suspected mucocutaneous HSV	13	12 (92.3%)
JC virus PCR (CSF)	Suspected PML	23	22 (95.7%)
Parvovirus PCR	Suspected red cell aplasia	19	17 (89.5%)
Parvovirus serology	None	7	0 (0%)
Toxoplasma CSF	Suspected Toxoplasma encephalitis	20	20 (100%)
Toxoplasma IgG	Unknown Toxoplasma serostatus	67	49 (73.1%)
Toxoplasma IgM	None	18	0 (0%)
VZV PCR (CSF)	Suspected VZV meningitis	21	20 (95.2%)
Total		1010	553 (54.8%)

Abbreviations: BAL, bronchoalveolar lavage; CMV, cytomegalovirus; CNS, central nervous system; CSF, cerebrospinal fluid; EBV, Epstein-Barr virus; HSV, herpes simplex virus; IGG, Immunoglobulin G; INSTI, integrase strand inhibitor; LFT, liver function test; PCR, polymerase chain reaction; PML, Progressive multifocal leukoencephalopathy; VZV, varicella zoster virus.

[a]One author (R.J.H.) feels that there is no indication for checking CMV PCR in patients with HIV who are not solid organ or hematopoietic stem cell transplant recipients.

subsequent hospital days. Although the hospital day on which a test was ordered did not correlate with test appropriateness overall ($P = .24$), for primary team housestaff the appropriateness of tests on the day of admission (45/112, 40.2%) was less than that of subsequent days (189/340, 55.6%; $P < .01$), perhaps reflecting supervision by attendings and consulting teams on subsequent days. This effect was not present in tests ordered by attendings ($P = .28$).

A total of 532 hepatitis serologies were ordered, only 52% of which were indicated. Of 102 hepatitis A IgM serologies ordered, only 25 (25%) were to evaluate acute transaminitis; others were ordered to evaluate chronic hepatitis or for hepatitis screening.

Similarly, only 26 of 109 hepatitis B core IgM serologies were ordered to evaluate acute hepatitis. Of note, 102 hepatitis panels were ordered (ie, all hepatitis A IgMs were ordered as part of the panel). Of 195 hepatitis A, B, and C IgG serologies, 136 (69.9%) were indicated, primarily for indications of hepatitis screening or evaluation for chronic hepatitis. Hepatitis PCRs and genotyping were less commonly ordered than serologies, with 21 hepatitis C PCRs, 7 hepatitis B PCRs, and 6 hepatitis C genotypes ordered during the study period. Of those ordered, 13 hepatitis C PCRs (61.9%) and 6 hepatitis B PCRs (85.7%) were indicated. None of the hepatitis C genotypes ordered during the study period were indicated, as no patient was under

Table 2. Number of Tests Ordered by Provider Type

Category	No. of Tests Ordered	
	Total	Indicated
Primary service		
CCU	12	1 (8.3%)
MICU	97	50 (51.5%)
Medicine hospitalist	278	166 (59.7%)
Medicine teaching	560	301 (53.8%)
Neurology	10	8 (80.0%)
Ob/GYN	20	12 (60.0%)
Psychiatry	3	0 (0%)
Surgical	30	15 (50.0%)
Ordering provider type		
Primary team intern/resident	452	234 (51.8%)
Primary team attending	323	183 (56.7%)
ID consult team resident	21	11 (52.4%)
ID consult team fellow	43	24 (55.8%)
ID consult team attending	24	21 (87.5%)
ER intern/resident	48	30 (62.5%)
ER attending	11	10 (90.9%)
Other consulting team intern/resident	8	6 (75%)
Other consulting team fellow	78	34 (43.6%)
Other consulting team attending	2	0 (0%)
Test recommended by ID		
Yes	402	264 (65.7%)
No	608	289 (47.5%)
Days since admission when test was ordered		
0	216	111 (51.4%)
1	196	113 (57.7%)
2	201	101 (50.2%)
3+	397	228 (57.4%)
Total	1010	553 (54.8%)

Abbreviations: CCU, cardiac care unit; ER, emergency room; ID, infectious diseases; MICU, medical intensive care unit; ObGYN, obstetrics/gynecology.

consideration for therapy (see Appendix Table 1 for further details).

A total of 19 CMV IgM serologies were ordered, 15 by teaching services and 4 by hospitalist services; no patient had suspected acute CMV acquisition. A total of 71 serum qualitative CMV PCRs and eight CMV quantitative PCRs were ordered; 59 (75%) were ordered by housestaff services and 20 (25%) by hospitalist services. Most qualitative PCRs (85%) were ordered for nonspecific signs of infection (eg, fever), and only 16 (22.5%) were indicated. In total, 10 patients were treated for CMV. Although 5 were treated for confirmed invasive disease, 2 patients received at least 1 dose of antiviral therapy on the sole basis of a positive serum CMV PCR, with no evidence of invasive disease. The other 3 were treated empirically for suspected invasive CMV disease pending diagnostic workup, but ultimately were not found to have invasive CMV disease.

Other tests ordered without clear indications included *Aspergillus* IgE, serum Epstein-Barr virus (EBV) PCR, parvovirus serology, and *Toxoplasma* IgM. Though only 1 patient in the study had suspected integrase strand inhibitor (INSTI)

resistance, 17 HIV Genosure/INSTI resistance tests (Monogram Biosciences, South San Francisco, CA) were ordered, typically in an effort to obtain routine HIV genotypes. Further analysis of the test ordering pattern for specific tests is available in the supplementary materials.

Overall, the estimated laboratory costs of inappropriate testing over the study period were between $14 000 and $92 000, depending on the cost database used (Medicaid vs FAIR Health). Acute hepatitis serologies inappropriately ordered to evaluate for chronic hepatitis were the largest contributors to cost, due in large part to the frequency with which they were ordered (Figure 1). CMV PCRs and HIV INSTI resistance testing were less commonly ordered but represented a large portion of costs due to their expense. On average, this represented a cost of $102–$670 per patient per year (FAIR Health database vs Medicaid reimbursement data) attributable to inappropriate laboratory utilization, ignoring pharmacy and other costs related to medical decisions made based on the results of inappropriate lab utilization.

DISCUSSION

Over the course of the study, nearly half of study tests ordered in HIV inpatients at a public teaching hospital were not indicated by our study criteria. We believe this is the first article to catalog specialized test ordering in the HIV-infected population. Although the number of tests involved is low, the expense of these tests is noteworthy.

The unfamiliarity with and complexity of testing in HIV patients present a likely contributor to the inappropriate testing observed in our study, particularly for nonhepatitis serologies and HIV Genosure testing. We feel that the contribution of CPOE cannot be understated, as test availability, default lab groups, and "lookalike" confusion in CPOE showed a clear correlation with ordering patterns in this study. Computerized entry makes it easy to order tests with a click of a button. In the era before CPOE, it was observed that removing less commonly ordered tests from paper requisition sheets led to decreased use of those tests [18, 19]. Prior studies have suggested that formal guidelines may be useful in guiding workup and limiting inappropriate testing in other settings [20]. Comprehensive HIV/AIDS opportunistic infection guidelines exist but do not address appropriate diagnostic workup for specific clinical syndromes [21]. To improve guideline use, it may be helpful to make a shorter, more accessible "pocket" version of guidelines that practitioners can access quickly when needed; this has been shown to be both a good source of information and well received by physicians in other specialties [22]. Similarly, such information could potentially be inserted into the CPOE system itself as a decision management tool to help providers, as has previously been performed with notifications about duplicate testing or testing cost [23–26].

Test availability and default settings in CPOE showed a clear correlation with ordering patterns in this study. Hepatitis
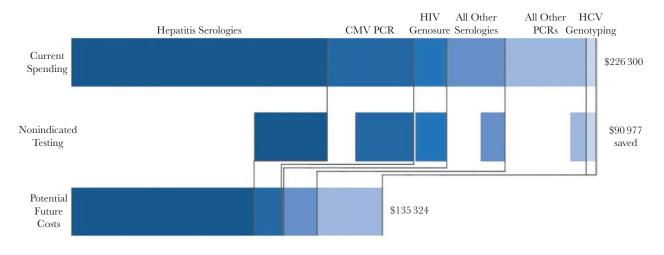
Figure 1. Potential savings from appropriate testing use based on the FAIR Health calculator with total spending on study tests over the 6-month study period, portion of cost spent on nonindicated testing, and potential future costs with appropriate testing. Comparable Medicaid costs: total spending $35 562, nonindicated testing cost $14 004, and potential future cost $21 558.

serology orders were a major contributor to both volume and cost of inappropriate testing, likely driven by the inclusion of IgM testing in our institution's default hepatitis panel (hepatitis A IgM, hepatitis B surface antigen, hepatitis B core IgM, hepatitis C IgG). These serologies were regularly ordered to evaluate for chronic hepatitis or for hepatitis screening, though the panel is designed for the evaluation of acute hepatitis or serum sickness. Other hepatitis serologies are available in CPOE but must be ordered individually, which places the burden on providers to recognize the correct, indicated serologies despite a misleading default workflow. This pattern of defaults driving ordering patterns has been previously demonstrated in other contexts, but our data suggest the importance of developing and labeling acute and chronic/screening hepatitis panels in CPOE [27]. Diagnostic algorithms have also been shown to improve hepatitis serology ordering patterns at other institutions [28].

The HIV INSTI resistance test serves as a clear example of the importance of careful consideration of EMR issues in diagnostic stewardship. Before this study, it was noted that most inpatient HIV genotypes ordered by providers at our institution were not indicated. Subsequently, genotype ordering was restricted to infectious diseases physicians, and the standard HIV genotype no longer would appear when other physicians searched for the word "genotype." However, during the same period, the order for HIV INSTI resistance testing was added to CPOE under the brand name "Genosure" and was not restricted. Therefore, many practitioners attempting to order an HIV genotype accidentally ordered the lookalike INSTI resistance testing. This phenomenon of lookalike test ordering has been observed in other settings as well [29]. Changes to CPOE orders at many health care institutions, including our own, require consensus among providers and stakeholders as to the need for and advisability of changes in the ordering process, which require approval at multiple committee levels. Subsequently, the timeline to actually implement the changes depends on the programming resources required and the priority assigned to the task. As it was anticipated that many months would pass before HIV INSTI resistance test ordering could be restricted, a concerted effort was made to educate internal medicine housestaff and hospitalists on the indications for INSTI resistance testing via announcements during lectures, morning reports, and Medicine Grand Rounds. Over the course of the study period, INSTI resistance testing orders initially peaked before eventually decreasing to a rate of 3 orders per month. Education may have been successful in this scenario, but it is a substantially weaker and less resilient quality improvement intervention, and uses time which could used to educate providers about other important topics.

Although the ordering process for INSTI resistance testing (a test for which there are substantially fewer stakeholders) was eventually changed to limit ordering to ID providers, discussions as to how to structure and implement hepatitis testing in the EMR are still ongoing. The tendency for less-than-perfectly-designed features to remain in the EMR due to bureaucratic inertia and economic factors, absent a strong institutional commitment to revise or remove these features, has been described elsewhere [30]. Conversely, the efficacy of integrated programs to rapidly detect changes in laboratory utilization, determine the root cause, and implement EMR solutions that lead to resolution of the problem has also been recently noted [31]. An alternative to EMR-based ordering restrictions would be postordering review with cancellation of inappropriate laboratory tests, as is frequently done with stool cultures ordered after 72 hours of hospitalization [32]. Although this can be an effective workaround to the EMR, postordering review consumes resources of its own and may be challenging to implement when the metric for assessing appropriateness of the test is more complicated than day of hospitalization.

Our study demonstrates the financial cost of inappropriate lab tests in this population. Laboratory tests represented $9.7 billion (3.4%) of the most recent Medicare costs and are one of the areas of most rapid cost growth [33]. We demonstrate that ordering unnecessary tests does not merely cost money but leads to inappropriate medication use. Our results add to the emerging evidence demonstrating the pivotal role that diagnostic stewardship plays in institutional antimicrobial stewardship as a whole. Unrestricted implementation of β-D-Glucan testing at one academic center without education of providers led to nearly 50% of ordered tests being inappropriate, leading to inappropriate use of antifungals when not clinically indicated [34].

Our study has numerous limitations. This was a retrospective, single-center study performed at an academic safety net hospital. The data were obtained in 2014, though we have no reason to believe that the issues we identified are any less pertinent in 2019. The study's location in the US South means that the findings may not be applicable to locations with different demographics of HIV infection [35] or with different patterns of testing utilization [32]. We did not assess reasons for hospitalization, which may be associated with volume of test ordering. However, reflecting the demographics of the HIV epidemic in the South, most admissions in general to our hospital in patients with HIV are for HIV-related reasons. Our 2 data sources yielded very different estimates of cost. However, health care costs are notoriously opaque, and frequently it is difficult or impossible to ascertain the "true" cost of a test or procedure [36]. We only estimated the direct costs of laboratory ordering and did not account for the costs of medications, procedures, or consultations resulting from the results of inappropriate testing; hence, our cost savings estimates may be too low.

Assessment of appropriateness was limited by the need to find justification for test ordering in the clinical documentation and was admittedly imperfect in the absence of clearly established guidelines as to the use of certain tests. Indeed, the authors of this study themselves disagree as to whether serum CMV PCR should be used to monitor treatment response in patients with HIV, as the data for CMV viral load monitoring for treatment response derive from the transplant literature [37]. The criteria for appropriateness are admittedly arbitrary, and it would be unfair to judge providers by criteria generated after the tests were ordered. We present our ordering criteria and the subsequent analysis as only suggested first steps to establishing which tests should be ordered in which circumstances, and we welcome further feedback and research on the topic.

Further studies should elucidate which diagnostic tests in which specific clinical scenarios lead to meaningful clinical diagnoses or to clinical management changes, and could be further expanded to repetition of tests such as CD4+ count or HIV viral load. The results of these studies could then be incorporated into guidelines as a way to improve diagnostic stewardship and could potentially be implemented via patient-specific and scenario-specific EMR tools. Although current iterations of EMRs typically do not allow for patient-specific stewardship, the increasing application of machine learning methods to health care suggest a potential future role of machine learning in identifying which diagnostic tests would be beneficial for a given patient [38].

Supplementary Data

Supplementary materials are available at *Open Forum Infectious Diseases* online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

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Appendix Table 1. Detailed Breakdown of Ordering Patterns and Indicated Nature of Each Test Analyzed in This Study

Category	Adenovirus AB (1)		Aspergillus IgE (7)		Aspergillus Ag (8)		Bartonella Ab (4)		CMV IgG (40)	
	Total	Indicated	Total	Indicated	Total	Indicated	Total	Indicated	Total	Indicated
Primary service										
CCU	-	-	-	-	-	-	-	-	2	1 (50%)
MICU	1	0 (0%)	3	0 (0%)	3	1 (33%)	1	1 (100%)	1	1 (100%)
Medicine hospitalist	-	-	-	-	1	0 (0%)	2	1 (50%)	10	8 (80%)
Medicine teaching	-	-	4	0 (0%)	4	0 (0%)	1	1 (100%)	26	20 (77%)
Neurology	-	-	-	-	-	-	-	-	-	-
Ob/GYN	-	-	-	-	-	-	-	-	-	-
Psychiatry	-	-	-	-	-	-	-	-	-	-
Surgical	-	-	-	-	-	-	-	-	1	1 (100%)
Ordering provider type										
Primary team intern/resident	1	0 (0%)	5	0 (0%)	6	1 (17%)	2	1 (50%)	25	19 (76%)
Primary team attending	-	-	2	0 (0%)	1	0 (0%)	-	-	8	7 (88%)
ID consult team resident	-	-	-	-	-	-	-	-	4	2 (50%)
ID consult team fellow	-	-	-	-	1	0 (0%)	-	-	2	2 (100%)
ID consult team attending	-	-	-	-	-	-	2	2 (100%)	1	1 (100%)
ER intern/resident	-	-	-	-	-	-	-	-	-	-
ER attending	-	-	-	-	-	-	-	-	-	-
Other consulting team intern/ resident	-	-	-	-	-	-	-	-	-	-
Other consulting team fellow	-	-	-	-	-	-	-	-	-	-
Other consulting team attending	-	-	-	-	-	-	-	-	-	–
Test recommended by ID										
Yes	-	-	-	-	2	1 (50%)	3	3 (100%)	30	24 (80%)
No	1	0 (0%)	7	0 (0%)	6	0 (0%)	1	0 (0%)	10	7 (70%)
Days since admission when test was ordered										
0	-	-	5	0 (0%)	3	0 (0%)	-	-	2	1 (50%)
1	-	-	1	0 (0%)	1	0 (0%)	-	-	9	7 (78%)
2	-	-	-	-	-	-	-	-	14	10 (71%)
3+	1	0 (0%)	1	0 (0%)	4	1 (25%)	4	3 (75%)	15	13 (87%)

Category	CMV IgM (19)		CMV PCR CSF (14)		CMV PCR BAL (1)		CMV PCR serum qual (71)		CMV PCR serum quant (8)	
	Total	Indicated	Total	Indicated	Total	Indicated	Total	Indicated	Total	Indicated
Primary service										
CCU	-	-	-	-	-	-	-	-	-	-
MICU	2	0 (0%)	-	-	1	1 (100%)	15	4 (27%)	4	3 (75%)
Medicine hospitalist	4	0 (0%)	6	6 (100%)	-	-	19	2 (11%)	1	1 (100%)
Medicine teaching	13	0 (0%)	6	6 (100%)	-	-	37	5 (14%)	3	1 (33%)
Neurology	-	-	2	1 (50%)	-	-	-	-	-	-
Ob/GYN	-	-	-	-	-	-	-	-	-	-

Category	CMV IgM (19)		CMV PCR CSF (14)		CMV PCR BAL (1)		CMV PCR serum qual (71)		CMV PCR serum quant (8)	
	Total	Indicated	Total	Indicated	Total	Indicated	Total	Indicated	Total	Indicated
Psychiatry	-	-	-	-	-	-	-	-	-	-
Surgical	-	-	-	-	-	-	-	-	-	-
Ordering provider type										
Primary team intern/resident	13	0 (0%)	4	4 (100%)	-	-	26	3 (12%)	4	1 (25%)
Primary team attending	5	0 (0%)	7	6 (86%)	-	-	37	5 (14%)	3	3 (100%)
ID consult team resident	-	-	-	-	-	-	1	0 (0%)	-	-
ID consult team fellow	-	-	-	-	-	-	3	2 (67%)	1	1 (100%)
ID consult team attending	-	-	2	2 (100%)	1	1 (100%)	-	-	-	-
ER intern/resident	1	0 (0%)	-	-	-	-	1	0 (0%)	-	-
ER attending	-	-	1	1 (100%)	-	-	2	1 (50%)	-	-
Other consulting team intern/resident	-	-	-	-	-	-	1	0 (0%)	-	-
Other consulting team fellow	-	-	-	-	-	-	-	-	-	-
Other consulting team attending	-	-	-	-	-	-	-	-	-	-
Test recommended by ID										
Yes	1	0 (0%)	12	12 (100%)	1	1 (100%)	42	10 (24%)	5	3 (60%)
No	18	0 (0%)	2	1 (50%)	-	-	29	1 (3%)	3	2 (67%)
Days since admission when test ordered										
0	6	0 (0%)	2	2 (100%)	-	-	7	1 (14%)	-	-
1	4	0 (0%)	2	2 (100%)	-	-	15	3 (20%)	-	-
2	4	0 (0%)	2	2 (100%)	1	1 (100%)	15	2 (13%)	2	1 (50%)
3+	5	0 (0%)	8	7 (88%)	-	-	34	5 (15%)	6	4 (67%)

Category	CMV PCR urine (1)		EBV IgG (1)		EBV IgM (1)		EBV PCR CSF (16)		EBV PCR serum (5)	
	Total	Indicated	Total	Indicated	Total	Indicated	Total	Indicated	Total	Indicated
Primary service										
CCU	-	-	-	-	-	-	-	-	-	-
MICU	-	-	-	-	-	-	2	2 (100%)	1	0 (0%)
Medicine hospitalist	-	-	1	(0%)	1	0 (0%)	5	5 (100%)	2	0 (0%)
Medicine teaching	1	0 (0%)	-	-	-	-	6	6 (100%)	2	0 (0%)
Neurology	-	-	-	-	-	-	1	1 (100%)	-	-
Ob/GYN	-	-	-	-	-	-	-	-	-	-
Psychiatry	-	-	-	-	-	-	1	0 (0%)	-	-
Surgical	-	-	-	-	-	-	1	1 (100%)	-	-
Ordering provider type										
Primary team intern/resident	-	-	-	-	-	-	5	5 (100%)	1	0 (0%)
Primary team attending	1	0 (0%)	1	0 (0%)	1	0 (0%)	8	8 (100%)	4	0 (0%)
ID consult team resident	-	-	-	-	-	-	-	-	-	-
ID consult team fellow	-	-	-	-	-	-	-	-	-	-
ID consult team attending	-	-	-	-	-	-	-	-	-	-

Appendix Table 1. Continued

Category	CMV PCR urine (1)		EBV IgG (1)		EBV IgM (1)		EBV PCR CSF (16)		EBV PCR serum (5)	
	Total	Indicated	Total	Indicated	Total	Indicated	Total	Indicated	Total	Indicated
ER intern/resident	-	-	-	-	-	-	1	1 (100%)	-	-
ER attending	-	-	-	-	-	-	1	1 (100%)	-	-
Other consulting team intern/resident	-	-	-	-	-	-	-	-	-	-
Other consulting team fellow	-	-	-	-	-	-	-	-	-	-
Other consulting team attending	-	-	-	-	-	-	1	0 (0%)	-	-
Test recommended by ID										
Yes	-	-	-	-	-	-	11	11 (100%)	1	0 (0%)
No	1	(0%)	1	(0%)	1	0 (0%)	5	4 (80%)	4	0 (0%)
Days since admission when test ordered										
0	-	-	-	-	-	-	3	3 (100%)	-	-
1	-	-	-	-	-	-	2	2 (100%)	-	-
2	-	-	-	-	-	-	1	1 (100%)	2	0 (0%)
3+	1	0 (0%)	1	0 (0%)	1	0 (0%)	10	9 (90%)	3	0 (0%)

Category	Enterovirus PCR CSF (1)		Hepatitis A IgG (24)		HIV Genosure (17)		HSV PCR CSF (41)		HSV PCR swab (13)	
	Total	Indicated	Total	Indicated	Total	Indicated	Total	Indicated	Total	Indicated
Primary service										
CCU	-	-	-	-	-	-	-	-	-	-
MICU	1	1 (100%)	-	-	-	-	4	4 (100%)	1	1 (100%)
Medicine hospitalist	-	-	8	7 (88%)	3	0 (0%)	12	12 (100%)	2	2 (100%)
Medicine teaching	-	-	15	12 (80%)	13	1 (8%)	22	19 (86%)	10	9 (90%)
Neurology	-	-	-	-	-	-	1	1 (100%)	-	-
Ob/GYN	-	-	1	1 (100%)	1	0 (0%)	1	0 (0%)	-	-
Psychiatry	-	-	-	-	-	-	1	0 (0%)	-	-
Surgical	-	-	-	-	-	-	1	0 (0%)	-	-
Ordering provider type										
Primary team intern/resident	1	1 (100%)	11	9 (82%)	8	1 (13%)	14	12 (86%)	8	7 (88%)
Primary team attending	-	-	6	5 (83%)	7	0 (0%)	11	11 (100%)	3	3 (100%)
ID consult team resident	-	-	1	1 (100%)	2	0 (0%)	-	-	-	-
ID consult team fellow	-	-	3	3 (100%)	-	-	-	-	1	1 (100%)
ID consult team attending	-	-	3	2 (67%)	-	-	-	-	-	-
ER intern/resident	-	-	-	-	-	-	12	10 (83%)	-	-
ER attending	-	-	-	-	-	-	2	2 (100%)	1	1 (100%)
Other consulting team intern/resident	-	-	-	-	-	-	2	1 (50%)	-	-
Other consulting team fellow	-	-	-	-	-	-	-	-	-	-
Other consulting team attending	-	-	-	-	-	-	-	-	-	-
Test recommended by ID										
Yes	-	-	19	17 (89%)	2	1 (50%)	17	17 (100%)	7	7 (100%)
No	1	1 (100%)	5	3 (60%)	15	0 (0%)	24	19 (79%)	6	5 (83%)

Appendix Table 1. Continued

Category	Enterovirus PCR CSF (1)		Hepatitis A IgG (24)		HIV Genosure (17)		HSV PCR CSF (41)		HSV PCR swab (13)	
	Total	Indicated	Total	Indicated	Total	Indicated	Total	Indicated	Total	Indicated
Days since admission when test ordered										
0	-	-	2	2 (100%)	3	0 (0%)	17	14 (82%)	2	2 (100%)
1	-	-	2	2 (100%)	5	0 (0%)	7	7 (100%)	3	3 (100%)
2	-	-	6	5 (83%)	4	0 (0%)	3	3 (100%)	3	3 (100%)
3+	1	1 (100%)	14	13 (93%)	5	1 (20%)	14	12 (86%)	5	4 (80%)

Category	Hepatitis A IgM (102)		Hepatitis B core IgG (5)		Hepatitis B core IgM (109)		Hepatitis B core total (25)		Hepatitis B PCR (7)	
	Total	Indicated	Total	Indicated	Total	Indicated	Total	Indicated	Total	Indicated
Primary service										
CCU	2	0 (0%)	-	-	2	0 (0%)	-	-	-	-
MICU	9	3 (33%)	1	1 (100%)	10	3 (30%)	1	1 (100%)	2	1 (50%)
Medicine hospitalist	25	7 (28%)	1	1 (100%)	25	6 (24%)	9	6 (67%)	1	1 (100%)
Medicine teaching	60	15 (25%)	3	3 (100%)	66	17 (26%)	15	13 (87%)	4	4 (100%)
Neurology	-	-	-	-	-	-	-	-	-	-
Ob/GYN	2	0 (0%)	-	-	2	0 (0%)	-	-	-	-
Psychiatry	-	-	-	-	-	-	-	-	-	-
Surgical	4	0 (0%)	-	-	4	0 (0%)	-	-	-	-
Ordering provider type										
Primary team intern/resident	44	11 (25%)	4	4 (100%)	51	13 (25%)	8	7 (88%)	5	4 (80%)
Primary team attending	35	13 (37%)	-	-	34	12 (35%)	4	2 (50%)	1	1 (100%)
ID consult team resident	1	0 (0%)	-	-	1	0 (0%)	-	-	-	-
ID consult team fellow	4	0 (0%)	-	-	4	0 (0%)	5	4 (80%)	-	-
ID consult team attending	-	-	-	-	-	-	1	1 (100%)	1	1 (100%)
ER intern/resident	4	0 (0%)	-	-	4	0 (0%)	-	-	-	-
ER attending	-	-	-	-	-	-	-	-	-	-
Other consulting team intern/resident	-	-	-	-	-	-	1	1 (100%)	-	-
Other consulting team fellow	14	1 (7%)	1	1 (100%)	15	1 (7%)	6	5 (83%)	-	-
Other consulting team attending	-	-	-	-	-	-	-	-	-	-
Test recommended by ID										
Yes	28	6 (21%)	1	1 (100%)	28	5 (18%)	12	10 (83%)	4	4 (100%)
No	74	19 (26%)	4	4 (100%)	81	21 (26%)	13	10 (77%)	3	2 (67%)
Days since admission when test ordered										
0	25	7 (28%)	-	-	27	7 (26%)	3	2 (67%)	-	-
1	25	6 (24%)	-	-	25	6 (24%)	1	1 (100%)	-	-
2	20	4 (20%)	1	1 (100%)	22	5 (23%)	8	5 (63%)	2	2 (100%)
3+	32	8 (25%)	4	4 (100%)	35	8 (23%)	13	12 (92%)	5	4 (80%)

Category	Hepatitis B surface AB (37)		Hepatitis B surface Ag (126)		Hepatitis C IgG (104)		Hepatitis C PCR (21)		Hepatitis C genotype (6)	
	Total	Indicated	Total	Indicated	Total	Indicated	Total	Indicated	Total	Indicated
Primary service										
CCU	-	-	2	0 (100%)	2	0 (0%)	-	-	-	-

Category	Hepatitis B surface AB (37)		Hepatitis B surface Ag (126)		Hepatitis C IgG (104)		Hepatitis C PCR (21)		Hepatitis C genotype (6)	
	Total	Indicated	Total	Indicated	Total	Indicated	Total	Indicated	Total	Indicated
MICU	3	3 (100%)	9	6 (67%)	9	6 (67%)	1	0 (0%)	-	-
Medicine hospitalist	14	9 (64%)	29	21 (72%)	26	18 (69%)	10	6 (60%)	1	0 (0%)
Medicine teaching	20	18 (90%)	68	48 (71%)	61	34 (56%)	10	7 (70%)	5	0 (0%)
Neurology	-	-	-	-	-	-	-	-	-	-
Ob/GYN	-	-	12	10 (83%)	2	1 (50%)	-	-	-	-
Psychiatry	-	-	-	-	-	-	-	-	-	-
Surgical	-	-	6	4 (67%)	4	2 (50%)	-	-	-	-
Ordering provider type										
Primary team intern/resident	12	11 (92%)	56	38 (68%)	46	27 (59%)	7	4 (57%)	5	0 (0%)
Primary team attending	7	5 (71%)	42	31 (74%)	34	25 (74%)	-	-	1	0 (0%)
ID consult team resident	1	1 (100%)	1	1 (100%)	1	0 (0%)	1	1 (100%)	-	-
ID consult team fellow	6	4 (67%)	5	2 (40%)	4	2 (50%)	-	-	-	-
ID consult team attending	3	3 (100%)	1	1 (100%)	1	1 (100%)	13	8 (62%)	-	-
ER intern/resident	-	-	4	2 (50%)	4	1 (25%)	-	-	-	-
ER attending	-	-	-	-	-	-	-	-	-	-
Other consulting team intern/resident	-	-	-	-	-	-	-	-	-	-
Other consulting team fellow	8	6 (75%)	17	14 (82%)	14	5 (36%)	-	-	-	-
Other consulting team attending	-	-	-	-	-	-	-	-	-	-
Test recommended by ID										
Yes	19	16 (84%)	32	20 (63%)	31	18 (58%)	5	5 (100%)	2	0 (0%)
No	18	14 (78%)	94	69 (73%)	73	43 (59%)	16	8 (50%)	4	0 (0%)
Days since admission when test ordered										
0	3	2 (67%)	36	27 (75%)	25	15 (60%)	6	3 (50%)	2	0 (0%)
1	4	3 (75%)	26	22 (85%)	25	18 (72%)	5	3 (60%)	-	-
2	9	8 (89%)	25	16 (64%)	23	11 (48%)	5	3 (60%)	1	0 (0%)
3+	21	17 (81%)	39	24 (62%)	31	17 (55%)	5	4 (80%)	3	0 (0%)

Category	JC PCR CSF (23)		Parvovirus PCR (19)		Parvovirus serology (7)		Toxoplasma CSF (20)		Toxoplasma IgG (67)	
	Total	Indicated	Total	Indicated	Total	Indicated	Total	Indicated	Total	Indicated
Primary service										
CCU	-	-	-	-	-	-	-	-	2	0 (0%)
MICU	3	3 (100%)	3	3 (100%)	1	0 (0%)	-	-	3	1 (33%)
Medicine hospitalist	10	10 (100%)	7	5 (71%)	2	0 (0%)	8	8 (100%)	22	16 (73%)
Medicine teaching	9	8 (89%)	9	9 (100%)	4	0 (0%)	10	10 (100%)	33	25 (76%)
Neurology	1	1 (100%)	-	-	-	-	1	1 (100%)	1	1 (100%)
Ob/GYN	-	-	-	-	-	-	-	-	-	-
Psychiatry	-	-	-	-	-	-	-	-	-	-
Surgical	-	-	-	-	-	-	1	1 (100%)	6	6 (100%)
Ordering provider type										
Primary team intern/resident	7	7 (100%)	10	10 (100%)	5	0 (0%)	7	7 (100%)	32	22 (69%)

Category	JC PCR CSF (23)		Parvovirus PCR (19)		Parvovirus serology (7)		Toxoplasma CSF (20)		Toxoplasma IgG (67)	
	Total	Indicated	Total	Indicated	Total	Indicated	Total	Indicated	Total	Indicated
Primary team attending	9	9 (100%)	4	3 (75%)	1	0 (0%)	6	6 (100%)	20	15 (75%)
ID consult team resident	-	-	1	1 (100%)	-	-	-	-	6	4 (67%)
ID consult team fellow	-	-	-	-	-	-	-	-	4	3 (75%)
ID consult team attending	-	-	2	2 (100%)	-	-	-	-	4	4 (100%)
ER intern/resident	5	4 (80%)	-	-	-	-	5	5 (100%)	-	-
ER attending	1	1 (100%)	-	-	-	-	1	1 (100%)	-	-
Other consulting team intern/resident	1	1 (100%)	-	-	-	-	1	1 (100%)	1	1 (100%)
Other consulting team fellow	-	-	2	1 (50%)	1	0 (0%)	-	-	-	-
Other consulting team attending	-	-	-	-	-	-	-	-	-	-
Test recommended by ID										
Yes	12	12 (100%)	9	8 (89%)	1	0 (0%)	10	10 (100%)	42	33 (79%)
No	11	10 (91%)	10	9 (90%)	6	0 (0%)	10	10 (100%)	25	16 (64%)
Days since admission when test ordered										
0	7	6 (86%)	1	1 (100%)	-	-	6	6 (100%)	10	6 (60%)
1	6	6 (100%)	3	2 (67%)	1	0 (0%)	5	5 (100%)	13	11 (85%)
2	2	2 (100%)	1	1 (100%)	1	0 (0%)	1	1 (100%)	17	12 (71%)
3+	8	8 (100%)	14	13 (93%)	5	0 (0%)	8	8 (100%)	27	20 (74%)

Category	Toxoplasma IgM (18)		VZV PCR CSF (21)	
	Total	Indicated	Total	Indicated
Primary service				
CCU	-	-	-	-
MICU	2	0 (0%)	-	-
Medicine hospitalist	2	0 (0%)	8	8 (100%)
Medicine teaching	11	0 (0%)	10	10 (100%)
Neurology	1	0 (0%)	2	2 (100%)
Ob/GYN	-	-	-	-
Psychiatry	-	-	1	0 (0%)
Surgical	2	0 (0%)	-	-
Ordering provider type				
Primary team intern/resident	14	0 (0%)	5	5 (100%)
Primary team attending	2	0 (0%)	5	5 (100%)
ID consult team resident	-	-	-	-
ID consult team fellow	-	-	-	-
ID consult team attending	2	0 (0%)	-	-
ER intern/resident	-	-	7	7 (100%)
ER attending	-	-	2	2 (100%)
Other consulting team intern/resident	-	-	1	1 (100%)

Appendix Table 1. Continued

Category	Toxoplasma IgM (18)		VZV PCR CSF (21)						
	Total	Indicated	Total	Indicated	Total	Indicated	Total	Indicated	Total	Indicated
Other consulting team fellow	-	-	-	-					
Other consulting team attending	-	-	1	0 (0%)					
Test recommended by ID									
Yes	3	0 (0%)	10	10 (100%)					
No	15	0 (0%)	11	10 (91%)					
Days since admission when test ordered									
0	7	0 (0%)	8	8 (100%)					
1	2	0 (0%)	5	5 (100%)					
2	4	0 (0%)	2	2 (100%)					
3+	5	0 (0%)	6	5 (83%)					

Abbreviations: BAL, bronchoalveolar lavage; CCU, cardiac care unit; CMV, cytomegalovirus; CSF, cerebrospinal fluid; ER, emergency room; ObGYN, obstetrics/gynecology; HSV, herpes simplex virus; ID, infectious diseases; MICU, medical intensive care unit; PCR, polymerase chain reaction; VZV, varicella zoster virus.