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Acta Clinica Belgica
International Journal of Clinical and Laboratory Medicine

ISSN: 1784-3286 (Print) 2295-3337 (Online) Journal homepage: http://www.tandfonline.com/loi/yacb20

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To cite this article: Ataman Gönel (2018): Clinical biochemistry test eliminator providing cost-effectiveness with five algorithms, Acta Clinica Belgica, DOI: 10.1080/17843286.2018.1563324

To link to this article: https://doi.org/10.1080/17843286.2018.1563324

Published online: 25 Dec 2018.

ACTA CLINICA BELGICA
https://doi.org/10.1080/17843286.2018.1563324

Clinical biochemistry test eliminator providing cost-effectiveness with five algorithms

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ABSTRACT

Objectives: The purpose of this study is to investigate the elimination ratios of requested unnecessary tests and the cost-effectiveness to be achieved by means of 5 different algorithms with clinical validity defined in an artificial intelligence program.

Methods: The clinician orders received from the hospital information management system were adapted to eliminate AST, direct bilirubin, chlorine, fPSA and fT3 tests using five different algorithms defined in the ALIN IQ software.

Results: In this study, 18387 AST, 9500 direct bilirubin, 61 free PSA, 1127 FT3 and 11172 chlorine tests that were ordered within 45 days were eliminated using 5 different algorithms defined in the ALIN IQ software in the Laboratory of Harran University Faculty of Medicine. USD 5592.76 was saved in 45 days. The annual saving is expected to be 363710 tests and USD 45363.49.

Conclusion: Five different tests were successfully eliminated with this study. Open-code smart softwares, which can create indefinite algorithms may be utilized as test eliminators in diagnostic clinical laboratories. Millions of dollars may be saved by means of such artificial intelligence softwares that can be adapted to any analyzer across the world.

KEYWORDS
test rejection; FT3; chlorine; AST; direct bilirubin

Introduction

Accurate management of information flow in large healthcare institutions is important in terms of efficient use of human and financial resources. Several commercial companies endeavor to develop their own information management system to achieve this goal. Tracking and accounting the materials utilized in hospitals depends on using these programs with the correct algorithms. Sometimes, thousands of algorithms may need to be identified in order to reduce unnecessary expenses in healthcare expenditure. Requiring some labor at the start, these algorithms provide time and money savings that compensate for more than the initial labor [1]. Unnecessary test requests not only increase costs but also result in loss of labor, and pave the way of overlooking true diseases due to intensity of work flow. This issue is taken into consideration throughout the world as a problem increasing healthcare expenditures, and resolution methods are being discussed. It has been reported that the cost of unnecessary tests in USA reach billions of dollars every year [2]. There are several studies in the literature on test utilization habits as well as studies on reducing laboratory costs [3,4]. Several studies have been conducted, including those with advisory guidance in hospital information systems to change the lab utilization habits of clinicians [5]. Inspecting laboratory utilization and providing training on lab costs for clinicians is a significant factor to reduce the number of tests [6,7]. The warning screens used in test elimination for laboratory tests is often regarded as annoying or disregarded by clinicians under heavy workload. Additionally, physicians concerned about increasing malpractice lawsuits which result in high indemnifications are also inclined to request more tests against the possibility of missing any disease [8]. In studies conducted to date, there have been attempts to perform test elimination mostly through measures during the pre-analytical phase. Emerging artificial intelligence programs employed in laboratory information management systems can ensure that certain tests are prevented at the analytical phase. Such programs allow thousands of algorithms regardless of the brand by allowing the entry of open codes. Using artificial intelligence programs for test prevention at the analytical phase may save millions of dollars. The purpose of this study is to investigate the elimination method of unnecessary tests and to provide cost-effectiveness through an artificial intelligence program in diagnostic biochemistry laboratories.

Methods

In this study, the clinician orders received from the hospital information management system were adapted to eliminate AST, direct bilirubin, chlorine,

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Table 1. Test and financial savings achieved according to 45 days of data.

	By defining five algorithms			Without algorithm	Achieved saving		
Tests	Before ALIN IQ	After ALIN IQ (a)	Change	Estimated number of tests expected to be performed according to the increased number of tests (b)	Number of tests saved (b-a)	Price of one test (cents)	Cost
AST	19,567	1,880	−18,387	20,809	−18,929	10.58	−$2,002.68
ALT	20,895	22,232	+1,337				
AST/ALT (%)	93.6	8.4	−85.2				
DBIL	11,989	2,489	−9,500	14,322	−11,833	10.58	−$1,251.93
TBIL	12,480	14,919	+2,439				
DBIL/TBIL(%)	96	16.6	−79.4				
FPSA	141	61	−80	160	−99	121.3	−$120.08
TPSA	219	249	+30				
FPSA/TPSA	64.3	24.4	−39.9				
FT3	2,155	1,028	−1,127	2,749	−1,721	53.52	−$921.07
FT4	4,024	5,140	+1,116				
TSH	5,795	7,577	+1,782				
FT3/FT4 (%)	53.5	20	−33.5				
Chlorine (Cl)	11,178	206	−11,172	12,465	−12,259	10.58	−$1,297
Potassium (K)	16,841	18,819	+1,978				
Sodium (Na)	16,831	18,774	+1943				
Cl/Na (%)	66.4	1.1	−65.3				
TOTAL					**−44,841**		**−$5,592.76**

free PSA and free T3 tests using 5 different algorithms defined in the ALIN IQ (Abbott, USA) software. From the test data to be sent by the software to Abbott c16000 biochemistry analyzer and Siemens Centaur XP hormone analyzer, it was requested to first run the ALT, total bilirubin, total PSA, TSH, FT4, Na and K tests requested by the clinician. After the aforementioned test results were obtained, the AST test was canceled for patients whose ALT test was in the normal range, direct bilirubin test was canceled for those whose total bilirubin test was in the normal range and free PSA test was canceled for those whose PSA value was in the normal range. Both TSH and FT4 tests were required to be in the normal range to cancel FT3. The FT3 test was run in the event that either result was outside the normal range. Na and K tests were required to be in the normal range in order to cancel the chlorine test. The chlorine test was run in the event that either result was outside the normal range. No prevention was made in cases where AST, direct bilirubin, chlorine, FT3 or Free PSA tests were ordered as single tests. Before and after completion of the algorithm, the number of tests performed through 45 days in the same period of 2017 and 2018 were compared and the change percentages were calculated as well as AST/ALT, direct bilirubin/total bilirubin, free PSA/total PSA, FT3/FT4 and Cl/Na ratios.

Results

A total of 20895 ALT tests and 19567 AST tests were run before the algorithms were defined and when the program was inactive. After introduction of the ALIN IQ program, 22232 ALT tests and 1880 AST tests were performed in a period of 45 days (Table 1). The number of ALT tests increased while the number of AST tests decreased by 85.2% with respect to the same period. The estimated number of AST tests expected to be performed according to the previously ordered ratios and according to the increased number of tests was estimated as 20809. According to this figure, the expected amount of saving is 18929 tests. Before ALIN IQ, the number of AST tests performed was 93.6% of the number of ALT test while after ALIN IQ, AST tests were only 8.4% of the number of ALT tests. A total of 12480 total bilirubin tests and 11989 direct bilirubin tests were performed before ALIN IQ. 79.4% of the total bilirubin tests were eliminated after ALIN IQ and although the number of total bilirubin tests increased to 14919, only 2489 direct bilirubin test were run with the algorithm. Before ALIN IQ, the number of free PSA tests performed was 64.3% of the number of total PSA tests while after ALIN IQ, 39.9% of the free PSA tests were eliminated and the number of free PSA tests was only 24.4% of the number of total PSA tests. Before the algorithm, the number FT3 tests performed was 53.5% of the FT4 tests while after the algorithm 33.5% elimination was achieved and only 20% of these tests were performed. The number of Cl tests decreased from 11178 to 206 with the algorithm. Before the algorithm, the number of Cl tests was 66.4% of that of sodium tests while the number of Cl tests was only 1.1% after the algorithm. About 65.3% elimination was achieved in Cl. USD 5592,76 saving was achieved with the five different algorithms implemented in 45 days. Figure 1 shows the changes in the number and ratios of AST, direct

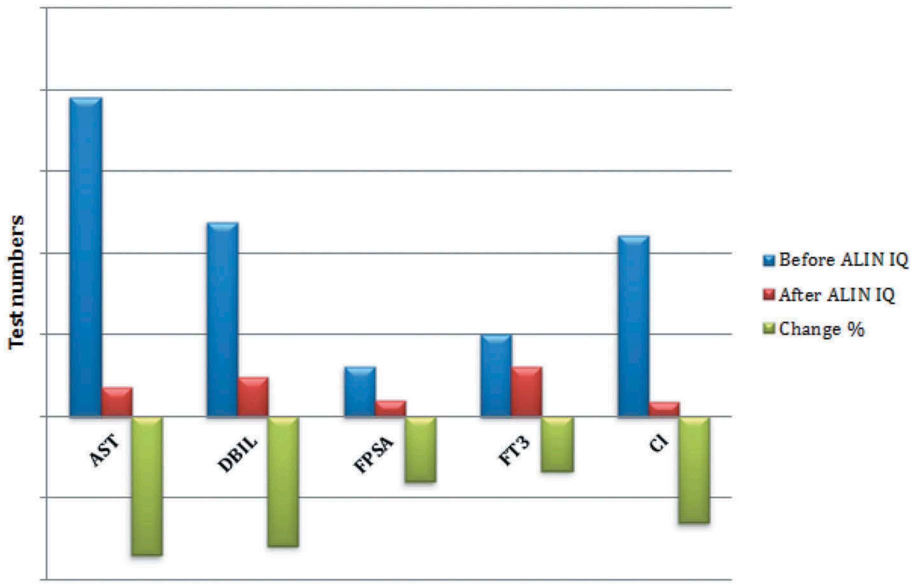

Figure 1. The number and change ratios of tests performed before and after the ALIN IQ program. (AST: aspartate transferase, DBIL: direct bilirubin, FPSA: free prostate specific antigen, FT3: free T3, Cl: chlorine).

bilirubin, free PSA, FT3 and chlorine tests performed before and after ALIN IQ.

Discussion

Unnecessary lab test orders, which has been the subject of several articles, are an important problem that increases healthcare expenditures [9,10]. The fact that all physicians receive their medical education in tertiary healthcare institutions where comprehensive researches are conducted, defensive medicine, fear of malpractice and lack of physician knowledge are among the reasons of requesting unnecessary tests [11,12]. Several methods have been attempted to prevent the increase in test costs and to improve test utilization. The implemented methods have mostly focused on the pre-analytical phase [13].

A meta-analysis study found informing clinicians and inspecting laboratory utilization to be effective in changing laboratory utilization habits [5]. In the model that was tried in a private hospital, the hospital information management system that allowed clinicians to make online test requests was rearranged for the correct use of tests. Advisory reminder notes were integrated into the system and a method was implemented to dissuade the physician. For example, for a test requested for the second time warning messages were created, such as 'You are requesting the same test for the second time' [14].

Another study showed that test requesting habits may change through trainings [15]. In these trainings, it was advised to target limiting the request of certain tests and changing test requesting habits [16]. In a study comparing two methods to inform clinicians, no feedback was provided to one group of clinicians while notifications were provided for a second group of clinicians regarding their lab utilization habits, and a document about cost-effective lab use was sent to one group and feedback was provided to the fourth group both about their own utilization and the cost-effective use of laboratory. The comparison showed that the most significant cost reduction was achieved in the fourth group with a rate of 42% [17].

Clinician Request Entry Screens are used for warning purposes in the implementation of the targeted strategies. Daily routine laboratory request panels created by clinicians constitute most of the requests made for inpatients. If these daily parameters are repeated within a period of less than 3 days, the system expects an explanation from the clinician and the requests can thus be limited. The test requests for inpatients were significantly reduced using this method used in a study [18]. The modification of test ordering screens is also one of the investigated methods. In one study, tests with limited benefit used more than necessary in the entry system were removed from the easy request screen and their requests were made more difficult. Unnecessary test requests were approximately halved with this approach [19]. Checking the request frequency of tests is one of the recommended methods. In a study on intensive care patients, it was prevented to request full blood, biochemistry and coagulation tests more frequently than 24 h, and it was reported that this attempt reduced the number of requests without any side effects on the patients or any impact on the discharge period [20].

Since preventing laboratory tests at the request phase restricts the freedom of clinicians, it creates a concern on timely diagnosis of diseases. Detecting at the analytical phase that related tests are unnecessary is a more acceptable method. Artificial intelligence programs can be very beneficial in preventing certain interrelated tests during the analytical phase. For example, AST is usually used in screening liver diseases and rises together with ALT [21,22]. The specificity of AST is low and it may rise in several diseases. The AST test may also be elevated in conditions such as hemolysis, intramuscular injection and extreme exercise [23]. Mildly elevated AST results are not considered as clinically significant as they are frequently encountered in hemolysis cases caused by sampling, and therefore their performance causes an unnecessary cost [24]. Muscular diseases are another case were AST is affected but ALT is not [25]. Using CK is more meaningful in conditions where muscular disease is considered. Therefore, an AST test requested in cases where ALT is normal may be canceled during the analytical phase. Total bilirubin rises in liver diseases and biliary tract obstructions [26]. It is used together with bilirubin for diagnostic purposes. It is meaningless to perform direct bilirubin test when total bilirubin is in the normal range; therefore, it is appropriate to cancel this test at the analytical phase. Total PSA levels increase in several prostate diseases and during prostate surgeries [27]. It is meaningless to perform free PSA test when total PSA is in the normal range and it can therefore be canceled during the analytical phase. Chlorine contributes to the regulation of osmotic pressure. It plays a role in regulating the acid-base balance. It is frequently observed together with excess sodium levels in the clinic in cases where chlorine intake is higher than its excretion. However, in cases of metabolic acidosis and alkalosis, it may decrease or increase independent of sodium status [28]. Clinicians request the blood gas test in metabolic ion shifts. Blood gas devices also run the Na, K and Cl tests as a single profile together with blood gases. Physicians were informed via the hospital information management system that physicians who wish to see chlorine results could contact the laboratory or that there was no restriction to request chlorine as a single test. There was no negative feedback regarding the cancellation of the Cl test after the algorithm was defined. The TSH and FT4 tests are requested while assessing thyroid functions by clinicians. It is not meaningful to perform the FT3 test when these two tests are normal. However, physicians are inclined to order these three tests simultaneously. FT3 levels may be important for endocrinologists in certain thyrotoxicosis cases, although rare. However, in such cases TSH or FT4 is likely to be affected as well. The algorithm defined in this study eliminates the FT3 test when the FT4 and TSH tests are in the normal range. Also, physicians who wish to see the FT3 test result can order FT3 alone, there is no restriction in this regard. Some physicians who noticed that any of these five tests was not run as a result of the defined algorithms stated that they were aware of the fact that the cancellation was made by the artificial intelligence when they contacted the laboratory. No negative feedback was encountered from clinicians about the test cancellations of artificial intelligence.

A significant number of unnecessarily ordered tests were eliminated using the algorithms implemented at the Clinical Biochemistry Laboratory of Harran University Practice and Research Hospital. In a period of 45 days; 18929 AST, 11833 direct bilirubin, 99 Free PSA, 1721 FT3 and 12259 chlorine tests not contributing to any clinical diagnosis or follow-up were canceled with the algorithms. When the algorithm detected a test required to be canceled, it prevented the order from being sent to the device. USD 5592.76 was saved from merely five simple algorithms in 45 days. The estimated savings at the end of 1 year is expected to be USD 45363. A total of 44841 tests were eliminated at the end of 45 days. The saving is expected to be 363710 tests and USD 45363.49 at the end of 1 year. This figure is equivalent to the annual number of tests and costs of a small-scale hospital. ALIN IQ and similar softwares may provide even further savings in hospitals with intense workload. In addition to elimination, the software we used can calculate the mean test results within the day to timely warn device users for systematic errors. Calibration shifts that occur within a day can be detected. With the 'delta check' feature it can warn the laboratory specialist during the approval stage in the event that the difference between the previous and current test results of a patient is above a certain rate. Also, the periods for waiting results may be reduced through automatic confirmation.

Conclusion

The advanced algorithms of such softwares that allow defining open codes regardless of the brand and model of devices may also be implemented on expensive hepatitis markers, specific immunoassay and PCR tests. Using artificial intelligence programs to eliminate unnecessary tests that constitute a significant cost in the healthcare expenditure of countries may provide millions of dollars of savings.

Disclosure statement

No potential conflict of interest was reported by the author.

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