# The Impact of a Clinical Decision Support System on the Utilization Pattern of Liver Ultrasound Examination

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**ABSTRACT** **Background:** In the past decade, numerous new imaging and laboratory tests have been implemented that significantly contribute to improved medical diagnostic capabilities. However, inappropriate utilization, which occurs on a large scale, has significant ramifications for both patient care and health systems.

**Objectives:** To assess the impact of a novel clinical decision support system (CDSS) applied to our electronic medical records on abdominal ultrasonography utilization pattern.

**Methods:** We conducted a retrospective cohort study comparing patterns of abdominal ultrasound utilization in cases of liver enzyme elevation, with and without CDSS, between February and May in 2017 (before CDSS implementation) and during the same months in 2018 (after CDSS implementation). The following parameters were collected: number of tests ordered according to the guidelines, tests with a diagnostic value, and order forms completed with any data or a diagnostic question. The comparison was conducted using chi-square test.

**Results:** Of 152 abdominal ultrasound tests, 72 were ordered in the pre-implementation period and 80 in the post-implementation period. The system failed to reach statistical significance regarding the rates of ordered tests according to the guidelines and/or tests with a diagnostic value. However, the use of the CDSS had a statistically significant impact regarding completing the order form with data, including a specific diagnostic question.

**Conclusions:** The effect of the system on the efficiency of test utilization was partial. However, our findings strongly suggested that CDSS has the potential to promote proper usage of complementary technologies.

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**KEY WORDS:** abdominal ultrasonography, clinical decision support system, electronic medical records

Various laboratory and imaging examinations consume a significant amount of hospital resources. Between 1999 and 2004, annual Medicare spending on diagnostic imaging in the United States increased from $5.8 billion to $10.9 billion. In Canada, diagnostic imaging accounts for almost 10% of the total annual healthcare costs with over CAD $1.5 billion spent in the province of Ontario alone [1]. Aside from the financial implications, other unfavorable outcomes of these tests included radiation exposure and risk of intravenous contrast-related side effects. This reality provides a substantial challenge to medical teams in terms of utilizing these tools intelligently and efficiently throughout inpatient treatment. Thus, the *Choosing Wisely* initiative was launched in 2012 by the American Board of Internal Medicine. The goal was to engage physicians and patients in conversations regarding the use of unnecessary diagnostic testing [2-5].

Despite the growing importance of clinical decision support systems (CDSSs) in improving care and lowering costs, there is little evidence they are widely used. A CDSS is defined as any electronic system meant to aid directly in clinical decision making in which patient-specific variables are exploited to generate patient-specific assessments or recommendations, which are then provided to physicians for consideration. [6].

The Department of Internal Medicine at Rambam Health Care Campus initiated the Specific, Measurable, Agreed, Required, and Timely (SMART) Medicine initiative to improve the effectiveness and efficiency of medical investigation by utilizing diagnostic tests more precisely to ensure that they are targeted, and clinically based [7,8]. The implementation of CDSS was a major component of the SMART Medicine effort, which also includes a multidimensional medical education campaign, SMART Medicine supportive working environment, and ongoing and rigorous monitoring and feedback [7,8].

We investigated the effect of a specific CDSS for liver ultrasound use in cases of elevated liver enzymes.

## PATIENTS AND METHODS

We collected data on all ultrasound tests conducted at Rambam Health Care Campus from February to May in both 2017 and 2018. Only cases in which the test was performed due to an indication of an increase in liver enzymes were included in the study. Cases in which indications were malignancy, cirrhosis, and alcoholic hepatitis were excluded.

The following parameters were collected and compared: tests ordered according to the guidelines, tests with a diagnostic value, order forms with any data, and order forms with a diagnostic question.

A test ordered according to the guidelines was considered as a test that was necessary to perform during hospitalization as it met at least one of the following criteria: an increase in liver enzymes more than 10 times the norm, an increase in liver enzymes less than 10 times the norm but in combination with an increase in total bilirubin above 2 mg/dl, and investigation of fever of unknown origin (FUO) or with symptoms or signs of cholecystitis/cholangitis. Symptoms or signs of cholecystitis include two of the following: fever, leukocytosis, and abdominal pain in the right upper quadrant (RUQ) when fever and leukocytosis alone are insufficient. The cholangitis symptoms include two symptoms of the Charcot Triad: fever, jaundice, and abdominal pain in the RUQ. When a test is requested for cholecystitis because of a tenfold increase in liver enzymes, but no symptoms or signs of cholecystitis were noted, the justification for the request is deemed illegitimate. The same applied for cases in

**Figure 1.** Liver ultrasound indications
ALP = alkaline phosphatase, ALT = alanine transaminase, AST = aspartate transaminase, FUO = fever of unknown origin, GGT = gamma-glutamyl transferase

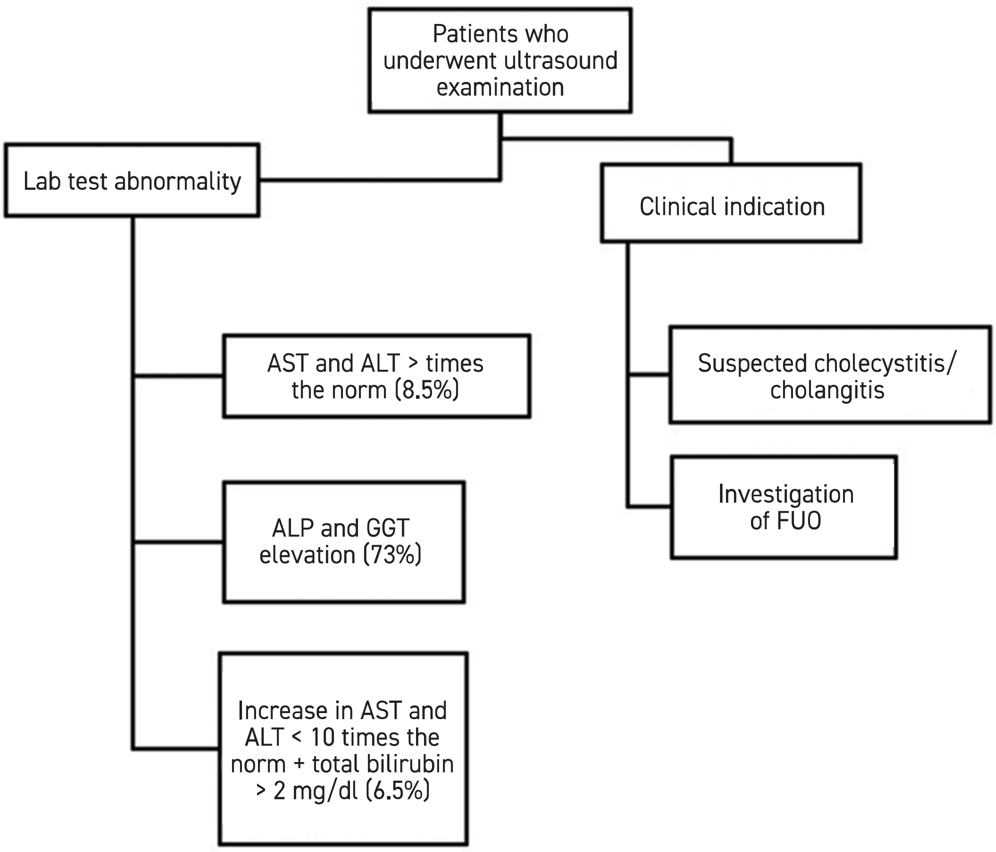

**Table 1.** Demographic and laboratory data of the study population

| Variable | Values |
|---|---|
| Age (years), mean ± SD | 66.09 ± 19.3 |
| Order to test time (days), mean ± SD | 1.57 ± 1.3 |
| Male:Female | 1.27:1 |
| ALT & AST > 10 times the norm (%) | 8.55 |
| ALP and GGT elevation (%) | 73.03 |
| Bilirubin > 2 mg/dl, AST and ALT elevated < 10 times the norm, and ALP and GGT within the norm (%) | 6.58 |

ALP = alkaline phosphatase, ALT = alanine transaminase
AST = aspartate aminotransferase, GGT = gamma-glutamyl transferase, SD = standard deviation

**Table 2.** Summary of the study findings

| Variable | 2017 | 2018 | *P*-value |
|---|---|---|---|
| TOAG (%) | 49.6 | 50.4 | 0.258 |
| Diagnostic value (%) | 48.4 | 50.6 | 0.899 |
| FOAD (%) | 15.3 | 62.5 | 0.000 |
| Diagnostic question (%) | 11 | 50 | 0.000 |

Diagnostic question = completing the order form with a question about specific diagnosis, FOAD = completing the order form with any data, TOAG = test ordering according to the guidelines

which there was an increase in gamma-glutamyl transferase (GGT) alone, or an increase in GGT and aspartate transaminase (AST).

When the ultrasound test revealed an illness or condition that resulted in liver enzyme elevation, a diagnostic value was assigned.

We found that some blank ultrasound test order forms had been sent; therefore, we added the parameters of *completing the order form with any data* and *completing the order form with a diagnostic question* to examine whether the SMART Medicine system led to any change.

## RESULTS

We obtained raw data on 383 individuals who had requested and completed an ultrasound test. After the data were processed, 152 cases were entered into the research. Of the 152 tests, 72 were performed in 2017, before the CDSS was implemented, and 80 tests in 2018 after introducing the CDSS.

The mean age of the patient study population was 66 years, with 67 women and 85 men. The indications [Figure 1] for the test were mainly severe hepatocellular liver enzymes elevation, cholestatic liver enzymes elevation, and bilirubinemia with mild to moderate hepatocellular liver enzymes elevation in 8.5%, 73%, and 6.6% of the tests, respectively. [Table 1].

We found no statistically significant effects of the system on the rate of ordering tests according to the accepted guidelines or with a diagnostic value. Similarly, when we analyzed the subgroup of patients who underwent testing due to an increase in cholestatic enzymes, no difference was found. However, when evaluating the effect of completing the order form with any data and completing the order form with a diagnostic question, the CDSS was shown to have a significant impact, with a *P*-value of 0.000 for each of these variables [Table 2].

## DISCUSSION

Physicians must justify performing a given test while being mindful of the benefits, risks, overall cost to society, and finite resources available. However, these clinicians are only partially aware that such behavior is expected of them, and thus improper use of tests occurs. The list of reasons for excess testing includes lack of knowledge, lack of confidence, defensive medicine, automatic behavior according to accepted norms, economic motivation, and illusion of control (performing unnecessary tests and procedures because physicians believe that their diagnostic tools and treatments are more effective than they actually are) [9]. Improper use occurs on a large scale and very little has been done to address this problematic phenomenon. A population-level analysis of seven low-value services, for which Choosing Wisely recommendations were issued, showed a modest decrease for only two of seven recommendations [10].

The SMART Medicine initiative provides a solution for proper use. Through education, working environment design, and introduction of CDSS, the SMART Medicine initiative promotes well-reasoned usage of complementary technologies (imaging modalities and laboratory tests) during medical investigation. As a real-time intervention, we introduced specific CDSSs into the patient's electronic medical record (EMR) to support physicians with decision making regarding the use of specific diagnostic tests. One of the CDSSs evaluated in this study focused on the process of ordering liver ultrasound in the presence of liver enzymes elevation.

The main justification behind the CDSS is growing concerns about the quality of medical care and discrepancies between real and ideal practice. CDSS is a health information technology designed to aid clinical decision-making. The characteristics of an individual patient are matched to a computerized clinical knowledge base, and patient-specific assessments or recommendations are then presented to the clinician for a decision.

In general, the efficacy of health information technologies in improving quality and efficiency have been demonstrated [11]. A systematic review from 2012 that evaluated the effect of CDSSs on clinical outcomes, healthcare processes, workload and efficiency, patient satisfaction, cost, and provider use and implementation found that both commercially and locally developed CDSSs are effective in improving healthcare process measures across diverse settings; however, evidence for clinical, economic, workload, and efficiency outcomes remains rare [6]. Griffey and co-authors [12] evaluated the impact of a real-time computerized decision support tool in an emergency department to guide medication dosing for elderly patients on physician ordering behavior and adverse drug events (ADE). They found that although overall agreement with recommendations was poor, real-time computerized decision support resulted in greater acceptance of medication recommendations. Fewer ADEs were observed when computerized decision support was active. The COMPETE II randomized trial showed that a shared electronic decision-support system to support the primary care of diabetes improved the process of care and some clinical markers of the quality of diabetes care [13].

Recently, the effectiveness of CDSS in altering clinician behavior has been variable [14,15]. Currently, it is a tool with limitations, unexpected results, and unintended consequences. Therefore, to achieve positive results its use should be selective, measured, and controlled [16]. With the integration of AI into CDSS, performance will be improved [17].

Currently our SMART CDSS is only knowledge-based, but we plan to integrate elements of machine-based learning, mainly to validate and/or deny current decision rules.

Our SMART CDSS knowledge base contains valid and up-to-date diagnostic rules and expert input. All of the SMART CDSSs have an inference engine that searches a patient's EMR clinical and laboratory data (i.e., values of liver enzymes), extracts key information, and analyzes it relative to rules from the knowledge base. Some of the information is automatically taken from the record and some from questioning the physician who ordered the test.

Based on the specific patient's data and the system's knowledge base, the communication mechanism allows the system to show the results and its recommendation to the user. Currently, and in accordance with the spirit of the project, the system allows the physician, in most cases, to ignore its recommendations and continue with test ordering.

Several features identified in our system are consistent with the recommendations for CDSSs in the literature [18].

- Assistance is offered to clinicians at the point of care in real-time.
- Computer-based representations of clinical logic and practice guidelines is provided.
- Current best literature-based and practice-based evidence is incorporated into the CDSS knowledge base.
- Specific definitions of the clinical context in which the CDSS knowledge is applicable are available.
- Customization of the literature-based evidence for local conditions is included.

Essentially, the CDSS delivers the right information (evidence-based guidance in response to clinical need) to the right people (physicians), through the right channels (the patient's EMR), in the right intervention format (chatbot), and at the right points in workflow (for decision making).

The effects of the system were less successful than expected and not optimal. The starting point was that unnecessary tests are being performed. We hypothesized that the system would reduce their number, which was not supported. However, we received clear proof that the physicians responded to the system and that it, in turn, affected their behavior. Therefore, we are convinced that a more advanced and smarter system will also affect their decision-making process.

## CONCLUSIONS

The SMART CDSS only partially fulfilled its expectations, but the study provided indications that deeper and broader implementation of an advanced version of CDSS has the potential to reduce the number of diagnostic tests and associated costs and to provide marked improvement to patient care.

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**Inspiration does not come like a bolt, nor is it kinetic, energetic striving, but it comes into us slowly and quietly and all the time, though we must regularly and every day give it a little chance to start flowing, prime it with a little solitude and idleness.**

Brenda Ueland (1891–1985), journalist, editor, freelance writer, and teacher of writing

**Capsule**

## Integrin α3 promotes TH17 cell polarization and extravasation during autoimmune neuroinflammation

The infiltration of CD4+ TH17 cells into the central nervous system (CNS) is a major driver of pathogenesis in multiple sclerosis (MS). Blocking lymphocyte trafficking to the site of autoimmune inflammation is a promising approach to treat MS, but the factors mediating the migration of TH17 cells are not well defined. **Park** et al. identified that integrin α3 is selectively expressed by pathogenic TH17 cells in a mouse model of experimental autoimmune encephalomyelitis (EAE) downstream of IL-6/STAT3 signaling. Integrin α3 stabilized the immune synapse through binding to its ligands on antigen-presenting cells, promoting the differentiation, expansion, and CNS infiltration of TH17 cells. These findings demonstrate that integrin α3 is a key determinant of TH17 cell pathogenicity in autoimmune neuroinflammation and is therefore an attractive therapeutic target for MS.

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