

Abdominal Cross-sectional Imaging for Inpatients With Abnormal Liver Function Test Results

Yield and Usefulness

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Background: Abdominal cross-sectional imaging is often performed to evaluate abnormal liver function test (LFT) results in hospitalized patients. However, few data are available regarding the yield and usefulness of imaging inpatients for the indication of abnormal LFT results, the process of requesting abdominal imaging studies, or the response to their findings.

Methods: We retrospectively reviewed abdominal imaging scans that were obtained during a 27-month period. We matched the imaging studies done with the indication of abnormal LFT results; all scans were requested using computerized physician order entry. Reports were coded for interpretation and associated process step results. To determine the usefulness of the imaging studies, a random sample of patient charts with positively coded imaging studies were reviewed. Imaging examinations were considered useful if they provided new diagnostic information and/or changed subsequent patient care.

Results: Of 6494 abdominal imaging studies, 856 were performed for the indication of abnormal LFT results and

matched to both image reports and laboratory results. Report coding judged 37% of interpretations as clinically significant, including 27% with "positive" (abnormal results and explain the abnormal LFT results) examinations. Among the positive examinations, the most common diagnoses were biliary obstruction (25%), cholecystitis (21%), malignancy (20%), and cirrhosis (14%). Positively coded reports provided new clinical information in 63% of these studies and changed patient care in 42% of cases. Process measures assessed provision of additional information to and from radiologists (69% and 8%, respectively) and the frequency with which the findings of current abdominal imaging studies were compared with those of prior studies (59%).

Conclusion: Abdominal cross-sectional imaging studies performed on inpatients with abnormal LFT results had a high diagnostic yield and frequently changed patient care.

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LABORATORY AND radiologic tests have 3 major roles in patient care: screening, diagnosis, and management¹; for abdominal imaging, diagnosis is most important. Noninvasive diagnostic imaging is frequently used in the evaluation and management of hospitalized patients with abdominal disease, especially in the hepatobiliary tract.² While imaging is often very useful, patients with liver disease can be accurately diagnosed with only a history, physical examination, and biochemical liver tests in an estimated 80% of cases.³ The primary modalities currently used for diagnostic imaging of the liver and biliary tract are ultrasonography (US), computed tomography (CT), and, to a lesser extent, magnetic resonance imaging (MRI).⁴ While radionuclide studies, such as hepatobiliary scintigraphy, are additional useful non-

invasive modalities, they are less frequently requested for the initial investigation of abnormal laboratory test results. Recent improvements in noninvasive technologies have markedly changed the roles of interventional techniques (angiography and cholangiography), and they are now used mostly in therapeutic or secondary diagnostic roles.² Cost has also become an important consideration in deciding how to best use these technologies.⁵

A common indication for inpatient abdominal imaging is to assist in the evaluation of abnormal liver function test (LFT) results.³ The liver function tests commonly include (individually or more commonly, in combination) the measurement of aspartate aminotransferase, alanine aminotransferase, total and direct bilirubin, and alkaline phosphatase levels. While the term *liver function tests* is a misnomer because abnormal values for most of these

PATIENTS AND METHODS

STUDY SITE

The study was conducted at Brigham and Women's Hospital, Boston, Mass, a 700-bed tertiary care teaching hospital. All inpatient diagnostic tests, including radiologic examinations, are ordered online using a computerized physician order entry.⁸ Clinical indications must accompany radiology requests and are chosen from preselected menus.⁷ Additional relevant information for the radiologist can be provided with the request as free text. Commercially available imaging equipment was used in the study (Somatom Plus 4 CT Scanner; Siemens Medical Systems, Iselin, NJ, and Acuson XP 128 Ultrasound Machine; Acuson Corp, Mountain View, Calif).

PATIENT POPULATION AND DATA

Using the hospital information system (Brigham Integrated Computer Systems, or BICS) database, we retrospectively identified all inpatients for whom abdominal imaging was requested and performed for the evaluation of abnormal LFT results during a 27-month period (December 1995–March 1998). All corresponding radiology reports were retrieved and matched to the electronic requisition. Imaging examinations completed prior to or after hospitalization were excluded.

OUTCOMES

The main outcome was the diagnostic yield of imaging studies performed because of abnormal LFT results. Secondary outcomes applied only to examinations with positive findings (defined below), and included the usefulness of the imaging findings and process measures associated with imaging requests and interpretations. Radiographic examinations were considered useful if they provided the clinician with new information and/or were determined to influence subsequent diagnostic or therapeutic decisions in patient care.

Radiology reports were reviewed and coded using a fixed coding scheme (**Table 1**) by an internist (J.M.R.). To assess reliability, a random sample of 17% of reports (n=145) were additionally coded by an abdominal radiologist (S.G.S.). Diagnostic results were considered significant if they were abnormal and explained the abnormal LFT results (positive group) or were abnormal and had significant findings, even if unrelated to the indication of

abnormal LFT results. Clinically insignificant results included normal or equivocal findings and abnormal findings that were judged to be insignificant.

For those examinations with a positive result, chart reviews were conducted on a random sample of 108 patient charts (47%) to address the clinical impact of performing imaging studies because of abnormal LFT results. Abstracting from the pretest progress notes, the investigators judged that the imaging findings provided new information if the results were not previously known (though may have been suspected in the differential diagnosis).

We also wanted to determine if these imaging studies resulted in changes in subsequent patient care, such as requiring additional confirmatory tests or assisting in therapeutic decision making (eg, changing code status in response to finding diffuse metastatic disease or postponing surgical intervention for improving fluid collections). Other examples of patient care influenced by imaging results included changes in medical therapy, surgical evaluation (with or without an operative intervention), or a subsequent procedure, such as endoscopic retrograde cholangiopancreatography or diagnostic biopsy. The impact of imaging studies on patient outcomes was not assessed.

Process measures of interest included how often abdominal imaging requests for evaluating abnormal LFT results included additional clinical information; how often radiologists provided specific recommendations (in addition to their interpretations); and how often radiologists included comparisons to prior studies. The investigators reviewed prior abdominal imaging reports for patients with positive findings. For determining the frequency of comparison reporting, the current report was noted for the presence of reference to prior abdominal CT or US. Prior studies were recorded for examination type (CT or US), for prior radiographic findings, and if they were conducted during the same hospitalization.

ANALYSIS

Radiographs were categorized as clinically significant or not clinically significant as described previously. Reliability for coding of imaging reports was assessed using the κ statistic and the percentage of agreement between reviewers. Diagnostic yield among different imaging modalities was compared using the χ^2 statistic. Differences in diagnostic categories for positive examinations by imaging modality were evaluated using a *t* test. Information given to radiologists and their recommendations were also compared using a *t* test.

tests actually reflect hepatocellular damage or dysfunction, not synthetic or metabolic function,⁶ it is widely used in the clinical vernacular.

While imaging is frequently performed in the inpatient setting to address this issue, few data are available regarding the yield in this population. Most studies have only investigated outpatient populations when evaluating the role of imaging modalities during the workup of abnormal LFT results.¹ While algorithms for choosing radiologic tests in the pursuit of a specific pathologic entity (eg, hepatic metastases) or a certain clinical presentation (eg, right upper quadrant tenderness with a palpable mass) have been developed,⁶ less information is available regarding the

evaluation of inpatients with abnormal LFT results as the primary indication for imaging requests.

Also, it has often been difficult to obtain detailed and accurate information about the indications selected by physicians who are ordering radiographs. However, at our institution, all radiographs are ordered online by physicians using a computerized physician order entry, resulting in nearly complete ascertainment of indications associated with examination orders.⁷

We used data from this computerized system to perform a study in hospitalized patients to assess the yield of abdominal imaging ordered for the indication of abnormal LFT results. Additional goals included

Table 1. Coding Scheme for Diagnostic Imaging Studies

Result Codes
1. Did the patient's history and/or signs and symptoms (selected from a menu of choices) accompany the x-ray requisition?
2. Was the radiologist provided additional clinical information (as free text)?
3. Were prior imaging studies (abdominal) performed? Did the radiologist compare the current study with the prior studies?
4. Were there any imaging recommendations made by the radiologist? If recommendations were made, were they for the same or a different modality?
5. Were there any nonimaging recommendations by the radiologist?
6. Diagnostic results
Positive: findings explain the indication (abnormal liver function test results)
Abnormal and likely significant: findings unrelated to the indication
Normal
Abnormal findings and likely significant
Abnormal findings of unknown significance
Equivocal findings
7. Diagnostic category

assessing the clinical usefulness of abdominal imaging for abnormal LFT results, categorizing the radiologists' diagnoses, and assessing several process steps associated with both requesting and interpreting abdominal imaging studies.

RESULTS

During the 27-month study period, there were 89450 adult admissions on the medical and surgical services. A total of 6494 abdominal imaging studies were performed on 3995 inpatients: 4404 CT scans, 1769 US scans, and 321 MRI scans. Of these studies, 1089 (17%) were performed to evaluate abnormal LFT results: 429 CT scans, 627 US scans, and 33 MRI scans (**Table 2**). Imaging requests not matching a radiology report were excluded (233 requests: 87 US scans, 113 CT scans, and 33 MRI scans), resulting in a final study group of 856 imaging studies (13%): 316 CT scans, 540 US scans, and 0 MRI scans.

DIAGNOSTIC YIELD

The coded results (n=856) were broadly divided into 2 groups: clinically significant (37%, n=313) and clinically not significant (63%, n=543; **Table 3**). Clinically significant findings were much more common among CT scans (180/316, 57%) than among US scans (133/540, 25%; $P=.001$). The former included findings that explained the abnormal LFT results (positive findings, 27% [n=229]), eg, biliary obstruction, as well as findings that, while unrelated to the abnormal LFT results, were considered significant and categorized as "abnormal, likely significant." The abnormal, likely significant studies (10%, n=84), though not read as positive, were considered important enough for inclusion in the clinically significant category. To be included in this category, an explanation of the abnormal LFT results was

Table 2. Abdominal Imaging Studies Ordered for Inpatients*

Examinations	Imaging Studies, No. (%)	No. of Patients
For indication of abnormal LFT results		
Total	1089	746†
CT	429 (39)	350
US	627 (58)	489
MRI	33 (3)	29
For indication of abnormal LFT results with matched reports		
Total	856	634†
CT	316 (37)	285
US	540 (63)	449
MRI	0	0

*LFT indicates liver function test; US, ultrasonography; CT, computed tomography; and MRI, magnetic resonance imaging.

†Patients may have undergone both US and CT (or MRI), resulting in total lower than sum.

Table 3. Abdominal Imaging Coded Results*

Result Code	No. (%)		
	CT	US	Total
Clinically significant ($P=.001$)			
Positive	112 (13)	117 (14)	229 (27)
Abnormal, likely significant	68 (8)	16 (2)	84 (10)
Clinically not significant ($P=.001$)			
Abnormal, likely not significant	52 (6)	179 (21)	231 (27)
Abnormal, unknown significance	50 (6)	111 (13)	161 (19)
Equivocal	28 (3)	36 (4)	64 (7)
Normal	6 (1)	81 (9)	87 (10)
Total	316 (37)	540 (63)	856 (100)

*CT indicates computed tomography; US, ultrasonography.

not met and many times was clearly unrelated, eg, finding a new renal mass suggestive of malignancy. The clinically not significant group was divided into "abnormal, likely not significant" (27%, n=231), such as an hepatic cyst; "abnormal, unknown significance" (19%, n=161), such as a retroperitoneal fluid collection; "equivocal" (7%, n=64), such as possible acalculous cholecystitis; and "normal" (10%, n=87). A second physician validated the reliability of report coding. The level of agreement between the 2 investigators for the sample was 87% ($\kappa=0.75$).

Examinations with positive findings were also classified by diagnostic categories (**Table 4**). Among both CT and US studies, the most common diagnostic categories were biliary obstruction/dilatation (25%); acute or chronic cholecystitis, without obstruction (21%); and mass(es) consistent with suspected malignancy, either primary or metastatic disease (20%). A greater proportion of malignancies were found on CT scans (CT, 29%; US, 10%; $P=.001$). Positive findings in the "other" category included suspicious hepatic fluid collections, such as hematomas or abscesses. As expected, the US examinations were proportionally more likely to be associ-

Table 4. Diagnostic Categories for Abdominal Imaging Examinations With Positive Findings*

	No. (%)			P
	CT†	US†	Total	
Biliary obstruction	21 (19)	36 (31)	57 (25)	.06
Cholecystitis	14 (12)	34 (29)	48 (21)	.005
Malignancy	33 (29)	12 (10)	45 (20)	.001
Cirrhosis	15 (13)	16 (14)	31 (14)	.80
Fatty changes	4 (4)	7 (6)	11 (5)	.35
Vascular abnormalities‡	3 (3)	7 (6)	10 (4)	.20
Other	22 (20)	5 (4)	27 (12)	.001
Total	112	117	229	

*CT indicates computed tomography; US, ultrasonography.

†Percentage calculation was within each modality.

‡Vascular abnormalities include hemangioma and portal vein thrombosis.

Table 5. Clinical Impact of Abdominal Imaging Results*

		No. (%)		
		CT† (n = 50)	US† (n = 58)	Total (n = 108)
Imaging→new clinical information	Yes	35 (70)	33 (57)	68 (63) (P = .16)
	No	15 (30)	25 (43)	40 (37)
Imaging→changes in patient care	Yes	25 (50)	20 (34)	45 (42) (P = .06)‡
	No	22 (44)	37 (64)	59 (55)
	Unknown	3 (6)	1 (2)	4 (4)

*CT indicates computed tomography; US, ultrasonography.

†Percentage calculation was within each imaging modality.

‡P, χ^2 excluding unknowns.

ated with abnormalities related to the biliary tract, such as obstruction (US, 31%; CT, 19%; $P = .06$) or cholecystitis (US, 29%; CT, 12%; $P = .005$).

Among the 84 examination findings judged as abnormal, likely clinically significant, CT scans were more often represented (68/316, 22%) than US scans (16/540, 3%). The most common diagnoses were bowel disease, such as colitis, obstruction, ischemia (19/84, 23%); pancreatic disease, such as inflammatory or infectious processes without biliary tract involvement (16/84, 19%); retroperitoneal adenopathy consistent with metastatic disease (10/84, 12%); nonhepatic solid organ masses with suspected malignancy (10/84, 12%); massive ascites (5/84, 6%); massive splenomegaly, without mention of portal hypertension or cirrhotic changes (4/84, 5%) and extrahepatic hematomas (4/84, 5%).

USEFULNESS

A sample of 108 medical charts were randomly selected from the positively coded group for review (**Table 5**). This sample represented 45% of the "positive" (abnormal results and explain the abnormal LFT results) CT scans (50/112) and 50% of the positive US scans (58/117). Imaging studies with positive findings provided new clinical information in 63% of cases (CT, 70%; US, 57%). The new information was sometimes under consideration and in the documented differential diagnosis, and some-

Table 6. Process Evaluation: Information Given to the Radiologist and Recommendations of the Radiologist

	No. (%)	
	Yes	No
Did the history and/or signs and symptoms accompany the x-ray requisition?	851 (99)	5 (1)
Did the radiologist get additional clinical information?	591 (69)	265 (31)
Were prior abdominal imaging studies performed?	261 (30)	595 (70)
Did the radiologist compare the current study with the prior studies?	153 (18)	108 (13)
Was there a change in studies compared with the prior studies?	124 (14)	29 (4)
Improvement	30	
Deterioration	94	
Imaging recommendation?	61 (7)	795 (93)
Same modality	10	
Different modality	51	
Nonimaging recommendations?	7 (1)	849 (99)

times represented an unsuspected finding. The diagnostic categories for imaging examinations that provided new information included common bile duct obstruction (22/68, 32%), mass or metastatic disease (12/68, 18%), fatty changes (11/68, 16%), associated pancreatic disease (8/68, 12%), and cirrhosis (4/68, 6%).

Positive imaging interpretations were associated with documented changes in patient care in 42% of studies (CT, 50%; US, 34%; **Table 5**). Categories of changes in patient care included medical therapy (16/45, 36%); endoscopic retrograde cholangiopancreatography, with or without a stent procedure (12/45, 27%); surgical evaluation, with or without surgical intervention (10/45, 22%); diagnostic biopsies (6/45, 13%); and drainage procedures (1/45, 2%).

PROCESS EVALUATION

Several process steps associated with the request and interpretation of abdominal imaging were examined (**Table 6**). Almost all (99%) radiology requisitions for abdominal imaging included additional patient history and/or signs and symptoms selected from the order entry menu choices. Additional clinical information was provided as free text in 69% of the requisitions. Free text examples include surgical history, hospital course before the imaging orders, patterns of abnormal LFT results, and results from previous or off-site imaging studies.

Further imaging or nonimaging recommendations in the radiology report were uncommon. Additional recommendations, such as may have taken place via phone calls or electronic mail sent to the attending physicians or in discussions with house staff during radiology rounds, were not addressed unless documented in the imaging report. The recommendations included further imaging in 61 cases (7%) and nonimaging recommendations in 7 cases (1%). The most common imaging recommendations were for MRI or CT scans following a completed US study. Nonimaging recommendations were still closely associated with additional imaging investigations, such

as suggesting gastroenterology evaluations for endoscopic retrograde cholangiopancreatography.

Prior abdominal imaging studies (either the same and/or different modality) were present in the BICS database for patients who underwent 261 of the current imaging studies (30%). Radiologists made comparisons to prior abdominal imaging studies for 153 of those examinations (59%). Current studies compared with prior imaging included 124 studies in which a change was noted (30 were improved and 94 were worse) and 29 studies in which there was no change. Findings that were worse included both progression of previously identified pathologic abnormalities or a new significant process. In 41% of those studies in which there were prior abdominal imaging examinations (108/261) (equivalent to 13% of the entire study group [108/856]), comparisons were not addressed in the current image examination interpretation. Lack of comparison reporting was much more frequent for US (106/108, 98%) than for CT (2/108, 2%). Previous studies omitted from report comparison with current studies included prior CT scans (alone) in 49 cases, prior US scans (alone) in 33 cases, and both imaging modalities previously performed in 26 cases.

COMMENT

Abdominal imaging, when performed in hospitalized patients because of abnormal LFT results, yielded clinically significant results in a surprisingly high proportion of cases. While both types of imaging have their indications, CT scans were more than twice as likely as US scans to be associated with clinically significant results. More than two thirds of positive examinations provided new information explaining the abnormal LFT results. The results of positive examinations contributed to changes in patient care in 42% of cases.

The interpretation of abnormal LFT results in the hospital setting, especially in complex or critically ill patients, can be challenging. The variable temporal relationship of individual laboratory result abnormalities to identifiable clinical events may lead to diagnostic obstacles. Liver function test results are more likely to reflect liver dysfunction occurring days to weeks before the date of laboratory test sampling rather than that same day.⁹ Additionally, mild abnormalities have been demonstrated to be frequent in healthy outpatients.¹⁰⁻¹² Abnormal LFT results may also transiently occur in hospitalized patients without liver disease, occasionally without explanation.¹³

The few studies that have been performed to assess the yield of abdominal imaging studies for the commonly used indication of abnormal LFT results have been done in outpatients. In a small prospective study of 83 patients with persistent (>6 months) elevation of aminotransferase levels, 65% of US studies yielded a pathologic explanation.¹¹ In jaundiced patients, the yield of hepatic imaging ranges from 52% to 69% to 94% to 97% of patients with a low and high pretest clinical suspicion, respectively.⁵ Compared with outpatients, an inpatient population would be expected to be relatively sicker, yet imaging could result in a lower yield, especially since many abnormal LFT results could occur as a result of hypo-

tension, infection, or medications. In all these situations, the abnormal LFT results would be expected to resolve as the underlying condition improves. However, diagnostic yield was high.

The abnormal, likely significant category included diseases of the bowel and pancreas, suspicious extrahepatic masses or fluid collections, massive splenomegaly, and retroperitoneal adenopathy. While such “unrelated” structural abnormalities cannot radiologically explain the abnormal LFT results, they are often associated with medical conditions resulting in hepatic pathophysiologic dysfunction. For example, abnormal LFT results may result from systemic insults remote from the hepatobiliary system, such as in multisystem organ dysfunction that is associated with sepsis or shock.¹⁴

Recent reviews of hepatobiliary tract imaging have suggested that while US remains the modality of choice for gall bladder disease, CT is emerging as the preferred test for the remaining disorders.² The other predominant noninvasive imaging technique, MRI, may be more informative in cases involving suspected hemangiomas, preexisting fatty infiltration with newly suspected hepatic lesions, and cholangiography in which therapeutic interventions are not expected.² In our study, US examinations were more likely to result in additional imaging studies (either a second US scan or a different modality, usually CT). Except in cases in which there is a high degree of suspicion of biliary tract or gall bladder disease, CT may be the more cost-effective initial imaging study in hospitalized patients with abnormal LFT results.

Chart reviews of patients with positive imaging results revealed that imaging in almost two thirds of cases provided new clinical information. Because imaging modalities were chosen by clinicians, and not randomized, differences in findings between CT and US cannot be assigned to the sensitivities of imaging tests for detecting various disease entities. For example, malignant lesions were more often found on CT scans, while biliary tract disease was more often found on US scans. Also, other clinical reasons may influence choice of modality, such as the practicality of US for critically ill patients at risk for transport to the radiology department or for pregnant patients because of the greater fetal risks from the radiation exposure of CT. Therefore, no conclusions can be made from our study with respect to diagnostic categories and the appropriateness of imaging modalities.

Patient care was determined to have changed in response to imaging results in 42% of reviewed charts with positive findings. Care included medical (36%) and interventional or surgical (64%) therapies. The medical responses included the addition, withdrawal, or modification of specific treatments. The nonmedical responses were predominantly for additional studies in the form of endoscopic retrograde cholangiopancreatography, surgical evaluation (with or without surgery), and diagnostic biopsies.

Determining the clinical impact of diagnostic imaging can be more difficult than for other types of technology assessment, especially therapeutic interventions. Imaging efficacy is considered an intermediate outcome.¹⁵ “Disaggregating” such diagnostic tests from treatment is difficult to impossible.¹⁶ Imaging influ-

ences management decisions, and those decisions may or may not improve patient outcomes. It may be reasonable, therefore, to consider management decisions as appropriate outcome measures for imaging studies.¹⁶ Nevertheless, modern imaging has been demonstrated to have an important impact on diagnostic decisions.¹⁷

Several components of the process of ordering and interpreting imaging studies in response to a specific clinical inquiry were addressed in this study, including documented information shared between clinicians and radiologists. Pertinent patient history (often including signs and/or symptoms) accompanied nearly all imaging requests. Study indications (in this sample, abnormal LFT results) accompanied all imaging requests. This success in providing radiologists with clinical information is attributable to the entry requirement built into the order screens. Clinicians must provide this information for imaging requests to be processed. Order entry screens facilitate this process by providing menus with preselected common indications. Also, entries can be manually entered for other indications or relevant clinical data.

In two thirds of imaging requests, additional information for the radiologist was provided as free text. Despite intuitive expectations as to their helpfulness, it is uncertain whether more robust clinical information accompanying imaging requests actually improves the diagnostic accuracy of imaging interpretations.

In addition to interpretation and differential diagnoses, radiologists occasionally provided management suggestions. In our study, radiologists made further recommendations in fewer than 10% of cases, and most often were suggestions to obtain additional imaging, usually with a different modality.

Comparisons to prior imaging studies were performed by the radiologist in fewer than two thirds of cases. In the remaining cases, although a prior abdominal imaging study had been performed, a comparison was not made. The low proportion of reported comparisons may be attributable to a variety of factors, including the inability to locate the prior studies in a timely fashion. The implementation of an electronic environment for delivery and interpretation of imaging studies and their reports (Picture Archiving and Communications Systems, or PACS) should decrease the number of cases in which a comparison is not made. Also, enhanced bidirectional communication between clinician and radiologist may be expected to be facilitated by computerization (eg, longitudinal electronic medical records).

Our study has several limitations. It took place in a single tertiary care institution. Because of this and the relatively large number of transplantation and oncology cases at our institution, our findings may not be generalizable to all hospitals. The contribution of imaging results to providing useful new information was analyzed by chart review only for studies with positive findings. Normal study results (or more commonly in our series, abnormal but not significant or of unknown signifi-

cance) may still provide valuable information in the evaluation of abnormal LFT results. For instance, excluding certain disease processes can avoid unnecessary exploratory procedures that were more common in the pre-CT era. Also, the completeness (and possibly the correctness) of chart documentation was inconsistent, and image reports were not available for about one fifth of the studies. Furthermore, we did not evaluate the utilization rates of abdominal imaging for all inpatients with abnormal LFT results. Finally, our definition of usefulness is based on implicit chart reviews, not on explicit criteria, and is subject to reviewer bias.

In summary, abnormal LFT results in hospitalized patients were frequent indications for ordering abdominal imaging studies. Imaging revealed significantly abnormal findings in about two fifths of studies. Positive imaging results frequently changed patient care. Further studies are needed to address the appropriateness and efficacy of abdominal imaging in inpatients with hepatobiliary disease.

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REFERENCES

1. Black ER. Diagnostic strategies and test algorithms in liver disease. *Clin Chem*. 1997;43:1555-1560.
2. Saini S. Imaging of the hepatobiliary tract. *N Engl J Med*. 1997;336:1889-1894.
3. Kamath PS. Clinical approach to the patient with abnormal liver test results. *Mayo Clin Proc*. 1996;71:1089-1094.
4. Taylor HM, Ros PR. Hepatic imaging: an overview. *Radiol Clin North Am*. 1998;36:237-245.
5. Burnett DA. Rational uses of hepatic imaging modalities. *Semin Liver Dis*. 1989;9:1-6.
6. Zakim D, Boyer TD. *Hepatology: A Textbook of Liver Disease*. Philadelphia, Pa: WB Saunders Co; 1998.
7. Harpole LH, Khorasani R, Fiskio J, Kuperman GJ, Bates DW. Automated evidence-based critiquing of orders for abdominal radiographs: impact on utilization and appropriateness. *J Am Med Inform Assoc*. 1997;4:511-521.
8. Teich JM, Hurley JF, Beckley RF, Aranow M. Design of an easy-to-use physician order entry system with support for nursing and ancillary departments. *Proc Annu Symp Comput Appl Med Care*. November 1992:99-103.
9. Tredger JM, Sherwood RA. The liver: new functional, prognostic and diagnostic tests. *Ann Clin Biochem*. 1997;34(pt 2):121-141.
10. Rubenstein LV, Ward NC, Greenfield S. In pursuit of the abnormal serum alkaline phosphatase: a clinical dilemma. *J Gen Intern Med*. 1986;1:38-43.
11. Hultcrantz R, Gabrielsson N. Patients with persistent elevation of aminotransferases: investigation with ultrasonography, radionuclide imaging and liver biopsy. *J Intern Med*. 1993;233:7-12.
12. Theal RM, Scott K. Evaluating asymptomatic patients with abnormal liver function test results. *Am Fam Physician*. 1996;53:2111-2119.
13. Lieberman D, Phillips D. "Isolated" elevation of alkaline phosphatase: significance in hospitalized patients. *J Clin Gastroenterol*. 1990;12:415-419.
14. Civetta JM, Taylor RW, Kirby RR. *Critical Care*. Philadelphia, Pa: Lippincott-Raven Publishers; 1997.
15. Thornbury JR. Intermediate outcomes: diagnostic and therapeutic impact. *Acad Radiol*. 1999;6(suppl 1):S58-S65.
16. Blackmore CC, Black WC, Jarvik JG, Langlotz CP. A critical synopsis of the diagnostic and screening radiology outcomes literature. *Acad Radiol*. 1999;6(suppl 1):S8-S18.
17. Dixon AK, Hollingworth W. Measuring the effects of medical imaging on physicians' diagnostic and therapeutic thinking. *Acad Radiol*. 1998;5(suppl 2):S274-S276.