# Managing Inappropriate Requests of Laboratory Tests: From Detection to Monitoring

*Maria Salinas, PhD; Maite López-Garrigós, PhD; Emilio Flores, PhD; Maria Leiva-Salinas, MD, PhD; Alberto Asencio, MD; Javier Lugo, MD; and Carlos Leiva-Salinas, MD, PhD*

## ABSTRACT

**OBJECTIVES:** The main objectives of this study were to show a simple approach to detect inappropriate requests of laboratory tests and to monitor success after establishing interventions. These objectives were monitored through process and outcome indicators customized according to the type and phase of the appropriateness strategy.

**STUDY DESIGN:** Quasi-experimental design.

**METHODS:** Based on evidence regarding laboratory test utilization differences among different geographical areas of Spain, we identified serum calcium (s-Ca) testing to be underrequested and total bilirubin (tBil) testing to be overrequested in primary care patients who undergo testing at the Public University Hospital of San Juan, in San Juan de Alicante, Alicante, Spain. Additionally, the ratio of free thyroxine (FT4) tests to thyrotropin (also called thyroid-stimulating hormone [TSH]) tests was well above the published 0.25 goal in primary care. Finally, numerous laboratory tests were overrequested in hospitalized patients due to repetitive testing. We designed and implemented a variety of strategies to correct such inappropriateness and designed different indicators to monitor the intervention success over time.

**RESULTS:** After implementation of the different strategies, the absolute number of s-Ca tests increased. The number of tBil tests in primary care, and numerous other tests repeated too frequently in hospitalized patients, decreased. The FT4/TSH indicator goal was reached and maintained over time. Regarding the outcome indicators, the strategy of reducing tBil tests in primary care and reducing the aggregate of unnecessary tests in hospitalized patients resulted in savings of $3543.80 and $9825.50, respectively, from January 2012 to December 2014. The s-Ca strategy, from November 2011 to December 2014, detected 62 subjects' primary hyperparathyroidism at a cost of $137.80 per case.

**CONCLUSIONS:** The study demonstrates a simple approach to detect inappropriate requests of laboratory tests, and how to assess the potential success of interventions using process and outcome indicators.

*Am J Manag Care*. 2016;22(9):e311-e316

Addressing inappropriate requests of laboratory tests is a great challenge for healthcare professionals; yet, due to the significant adverse effects of such requests, it is worth tackling.[1-6] Although underrequesting may result in missing a diagnosis, overrequesting may generate as many as 3 major adverse effects: 1) economic costs—although the individual cost of a single test may seem low, the cumulative effect of unnecessary tests is high, as they generate high costs due to their high request[7]; 2) adverse effects of false-positive results—these can produce additional side effects, including the costs of additional medical consultations and diagnostic tests, and the collateral effects of Ulysses[8] and Imaginary Invalid syndromes[9]; and 3) increasing commoditization of the laboratory—the laboratory may be seen more as a "data vending machine" than as a provider of knowledge,[10] and it might deliver results that are possibly misinterpreted or create a scenario in which those results with high clinical value are "hidden."[11] Given these issues, it is crucial to reduce variability of laboratory testing in clinical practice.[12] Indeed, establishing interventions in collaboration with all the stakeholders involved in healthcare is a key element for better efficiency in clinical decision making.[13,14]

The first objective of this study is to propose an intervention that can detect inappropriate requests of laboratory tests. The second is to monitor the course of the intervention over time through process and outcome indicators, customized according to the type and phase of the appropriateness strategy.



## METHODS

### Setting

Through the National Health System, every citizen of Spain has access to public health services. The system divides Spain into health departments, each of which covers the healthcare necessities of a population living in a particular geographic area through several primary care centers and a hospital. The laboratory located at each hospital attends to the needs of every inhabitant of that health department.

## TAKE-AWAY POINTS

- Addressing inappropriate laboratory orders is a great challenge for laboratory professionals.
- The aim of this study was to show a simple approach to detecting inappropriate laboratory orders.
- Indicators customized according to the type and to the phase of the appropriateness strategy are essential to being able to measure the potential impact on the patient's diagnosis.

The study was conducted from January 1, 2010, to December 31, 2014, in the clinical laboratory at the Public University Hospital of San Juan, a suburb of Alicante, Spain. This 370-bed suburban community hospital serves a population of 234,551 who utilize 9 different primary care centers (PCCs). It receives samples from hospitalized patients, outpatients, and primary care patients (PCPs).

Hospitalized patients' samples are collected in every ward by nurses and then transported to the laboratory. The hospitalized patient and outpatient orders are entered manually in the laboratory information system (LIS); however, PCPs' requests are ordered electronically by the general practitioners (GPs). Blood is drawn for PCPs in the PCC. Samples are transported by couriers following scheduled routes covering the PCCs and are delivered to the laboratory sample reception desk. Subsequent reports are sent electronically from the LIS to the PCP's electronic health record.

### Detection of Inappropriate Requests

In 2010, based on test utilization differences among Spanish geographical areas,[15] overrequests of free thyroxine (FT4) tests were noted in primary care via the indicator that measures the ratio between the tests requested of FT4 and of thyrotropin (also known as thyroid-stimulating hormone [TSH]). The ratio of FT4/TSH equaled 0.42, which did not reach the published <0.25 indicator goal.[16] We also detected a significant underrequest of serum calcium (s-Ca) tests and an overrequest of total bilirubin (tBil) tests in PCPs, through the indicators, "test requests per 1000 inhabitants" (37 and 56 tests per 1000 inhabitants for s-Ca and tBil, respectively).

For hospitalized patients, redundant requests of brain natriuretic peptide (BNP); ferritin; folate; glycated hemoglobin (A1C); high-density lipoprotein cholesterol (HDL-C); immunoglobulin G, A, and M (IgG, IgA, IgM, respectively); iron; and prostatic specific antigen (PSA); as well as rheumatoid factor, transferrin, triglycerides, and vitamin B12, were identified. We considered a test redundant when it was requested before an established interval; for instance, requesting a rheumatoid factor test when one had been performed just 2 days earlier was considered redundant.

### Implementation of Strategies

To address the problem, we designed and established 4 strategies in consensus with GPs and the test-requesting hospital physicians. The first strategy, implemented in PCCs, is that the LIS discards FT4 when the TSH value is in reference range, unless the FT4 measurement is specifically requested by the GP. The second strategy, also implemented in PCCs, is that the LIS automatically adds s-Ca to the GP requests made for patients 45 years or older who have not had the test in the previous 3 years.[17]

GPs agreed with these 2 interventions during various meetings; patients provided verbal consent for conducting a biochemical examination at the moment of the request by the GP. However, if, for some particular reason, a clinician justifies the relevance of an automatically cancelled FT4 test for a specific patient, this test is registered again.

The third strategy consists of measuring tBil only when the icteric index is above 2 mg/dL (34.2 µmol/l).[18] The icteric index is a very accurate semi-quantitative surrogate of tBil. When the index is below 2 mg/dL (34.2 µmol/l), tBil is reported through a comment, such as "with a confidence interval of 99%, tBil result is below 1.2 mg/dL (20.5 µmol/l)." This strategy was applied to every type of patient.

The fourth strategy involved hospitalized patients. If previously requested and completed in the past 7 days, the LIS would automatically negate requests for tests of total cholesterol, HDL-C, or A1C. If previously requested and completed in the past 3 days, the LIS would automatically negate requests for tests of BNP, ferritin, folate, IgG, IgA, IgM, iron, PSA, rheumatoid factor, transferrin, triglycerides, or vitamin B12.

**eAppendix Table A** (eAppendices available at **www.ajmc.com**) illustrates the different steps of the proposed approach to identify and correct potential inappropriate use of laboratory tests. The strategies to reach appropriate request levels of FT4, s-Ca, and tBil in primary care, and the intervention for the aforementioned tests in hospitalized patients, were established in May 2011, November 2011, January 2012, and March 2012, respectively. From October 2012 to January 2013, the s-Ca strategy stopped for preliminary evaluation, then the strategy was reinstituted in January 2013. The rest of the measures were continuous.

This study was approved by the Hospital Research Committee of the Public University Hospital of San Juan.

### Monitoring Through Process and Outcome Indicators

The strategy that discards FT4 when the TSH value is in the reference range was monitored through the ratio of requests of both tests. The strategy to increase the measurement of s-Ca in PCPs was monitored through the process indicator: the absolute number of s-Ca tests that were added. This strategy was also monitored through the indicator that relates s-Ca to serum glucose (s-Glu) requests. To control that the predicted increase in s-Ca requests was indeed due to the intervention and not a general trend, we also calculated the ratio of serum creatinine to s-Glu requests. The intervention to request tBil testing through a com-

ment, when the icteric index is below 2 mg/dL (34.2 µmol/l), was monitored through the process indicator of number of patients whose tBil was not measured.

The strategy that eliminated the aforementioned tests (total cholesterol, BNP, etc) in hospitalized patients when requested too soon (as described) after previous identical measurements was evaluated monthly, utilizing the counts of tests that were cancelled.

We calculated the following outcome indicators: number of new cases of primary hyperparathyroidism (HPT) detected; the economic cost per new HPT diagnosis derived from an s-Ca test added from the clinical laboratory (calculated by dividing the total amount of s-Ca reagent costs by the number of new HPT cases); and economic savings that resulted from the decrease in tBil measurement and from cancelling the hospitalized patients' tests that were deemed redundant because identical ones had recently been performed. To calculate these savings, the tBil and redundant tests that would have been performed were counted, and the total was multiplied by the price of the reagent that would have been used (other "saved" laboratory fees were not included). **eAppendix Table B** summarizes the different indicators that were used to track and monitor the different interventions after their establishment.

**TABLE.** Number of Requests and Tests Received Annually From PCPs and From Hospitalized Patients

| | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|
| PCP requests | 87,252 | 91,669 | 87,469 | 95,018 | 97,557 |
| PCP tests | 995,093 | 1,086,875 | 965,411 | 1,157,681 | 1,313,190 |
| Hospitalized patients' requests | 9623 | 9156 | 9214 | 9884 | 9694 |
| Hospitalized patients' tests | 207,322 | 197,760 | 190,941 | 198,299 | 216,258 |

PCP indicates primary care patient.

## RESULTS

The **Table** shows the number of requests and tests received annually on behalf of PCPs and hospitalized patients from January 1, 2010, to December 31, 2014.

**Figure 1** shows the evolution of the FT4/TSH indicator value for primary care on a monthly basis. The indicator goal was reached in May 2011 and has been maintained ever since.

There was a significant increase in the number of s-Ca tests from primary care that were added at the beginning of the implementation of the strategy, then 3 months with no extra s-Ca because of the intervention evaluation period, and finally a gradual decrease in the number of s-Ca added as the number of patients screened for PHPT increased (**Figure 2**). The indicator that relates s-Ca to s-Glu request followed the same pattern (Figure 2). There was also an increase in the total requests of tBil, (24,658 in 2012, 25,437 in 2013, and 30,979 in 2014) and tBil not measured. The number of tBil tests that were not measured, but reported through a comment, is shown in **Figure 3**.

**Figure 4** shows the total number of tests that were deemed unnecessary and were cancelled in hospitalized patients.

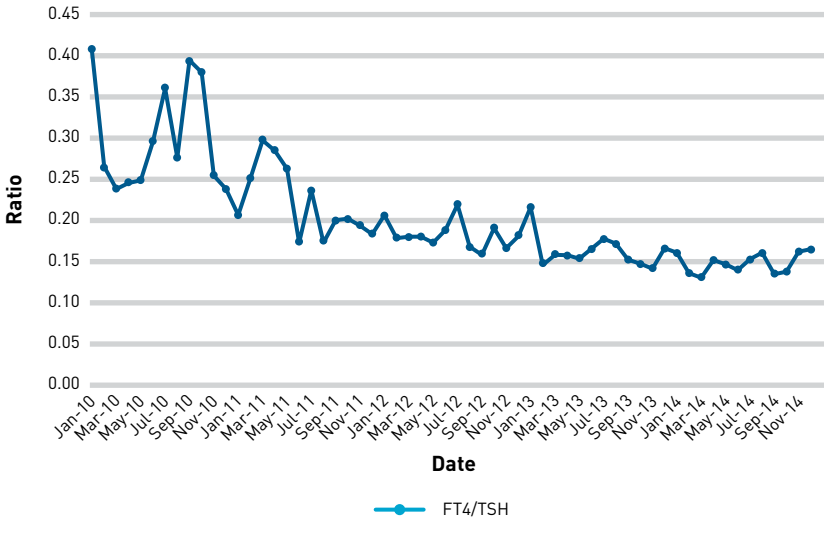
The outcome indicators demonstrate that, thanks to the s-Ca strategy, 62 new, previously unidentified cases of HPT were detected between November 2011 and December 2014, with each detection costing $137.80.

From an economic perspective, regarding the outcome indicators, the strategy of reducing tBil tests in primary care and reducing the unnecessary tests in hospitalized patients resulted in savings of $3543.80 and $9825.50, respectively, from January 2012 to December 2014.

## DISCUSSION

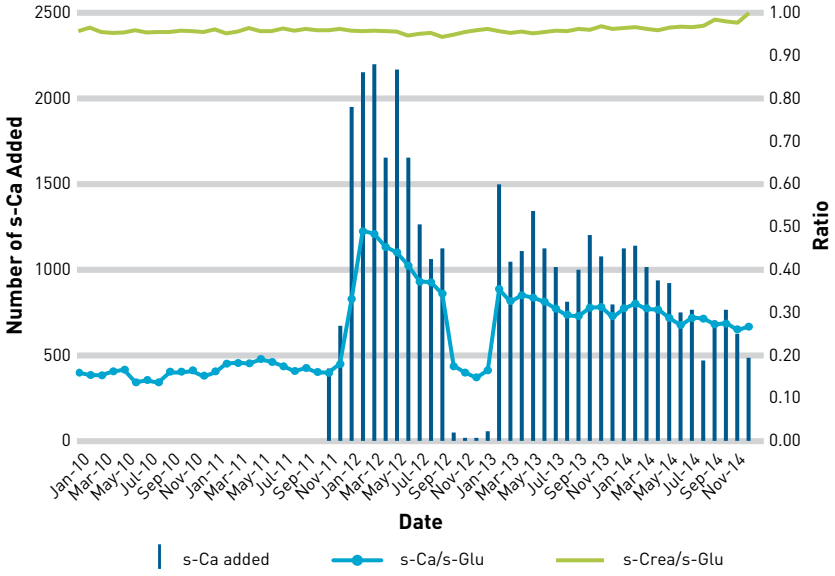
Our study demonstrates how simple approaches can detect inappropriate requests of laboratory tests, as well as monitor—at a glance—postintervention success, using process and outcome indicators that have been customized according to the type and

**FIGURE 1.** Temporal Evolution of the Absolute Number of the FT4/TSH Ratio[a]




FT4 indicates thyroxine; TSH indicates thyroid-stimulating hormone or thyrotropin.
[a]This figure shows the evolution of the ratio by month, January 2010 to November 2014. The strategy to reach an appropriate request level of FT4 tests in primary care was established in May 2011.

**FIGURE 2.** Temporal Evolution of the Number of s-Ca Tests Added and the s-Ca/s-Glu and s-Crea/s-Glu Indicators[a,b]




s-Ca indicates serum calcium; s-Crea, serum creatinine; s-Glu, serum glucose.
[a]This figure shows: a) the number of s-Ca tests that were added from the laboratory in patients aged 45 years or more who had not had an s-Ca test in the previous 3 years, and b) the monthly evolution of the s-Ca/s-Glu request indicator.
[b]To check that any potential increase in the request of s-Ca was indeed due to the strategy and not to a random trend, we also calculated the ratio of s-Crea to s-Glu. Note that from October 2012 to January 2013, the strategy stopped only for evaluation purposes.

stage of the strategy. The measurement of outcome indicators is essential to calculate if the clinical laboratory is contributing appropriately in terms of patient results and economic savings (ie, achieving the highest contribution to the diagnosis, monitoring, and prevention of disease at the lowest cost).[19]

The first step in any intervention of this kind is to determine whether there is over- or underrequesting of laboratory tests; the second is to correct such inappropriateness through strategies approved by requesting clinicians; and the third is to monitor the corrective interventions after their establishment.

Studies to identify inadequacies in test requests by reviewing patients' medical records are expensive, cumbersome, and difficult to perform. However, identifying such inadequacies is possible—using indirect means—by measuring differences in test utilization among geographical areas (ie, multiple countries or regions within a single country).[20,21] Indicators that can be used in such scenarios include the number of tests per 1000 residents in a certain area[13,22,23] or per 1000 medical admissions,[22] test-ordering ratios,[24] or by comparing the number of requests with guidelines or disease prevalence.[25,26] In our case, we detected that the relative ratio of FT4 and TSH testing was not in accordance with a published, generally accepted (in Spain) target of <0.25.[16] Additionally, the underrequesting of s-Ca tests was detected in our region by utilizing the indicator "requests per 1000 inhabitants," which was significantly lower than in other Spanish areas.[15] Testing for tBil was considered to be inappropriate since it is not recommended as a screening method for liver disease in primary care.[27]

A second way to detect whether over- or underrequesting is taking place is through retrospective studies of the number of requests in the LIS patient database. In fact, we utilized this approach to identify inappropriate test requests for hospitalized patients. Unnecessarily repetitive testing was observed for certain tests—probably due to human error, as hospitalized patients' medical records were kept manually, not with computers.

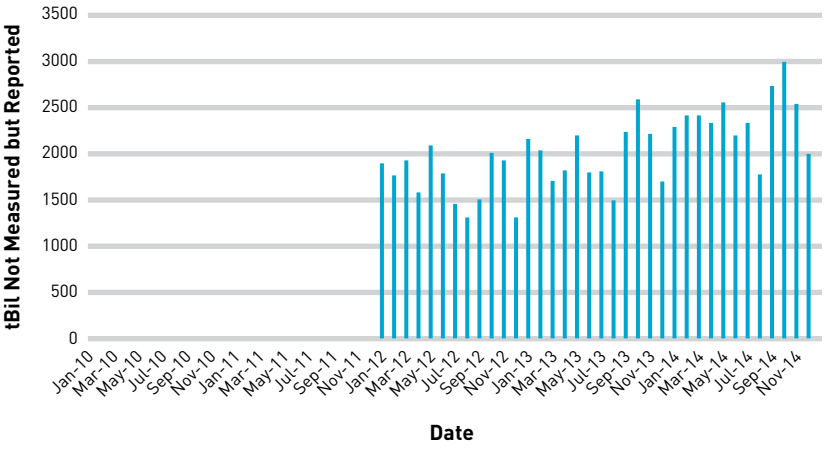
Once inappropriate testing levels have been identified and addressed, indicators play a crucial role in evaluating the success of interventions and to check if they are maintained over time. Regarding process indicators, for instance, as was expected, once the s-Ca strategy was established, the requests for this test began to increase, both in absolute numbers and relative to the s-Glu test requests. When relative indicators are used, it is important to also measure, simultaneously, a warning indicator referring to a test whose demand is not influenced by the strategy to identify potential external confounding factors not related to the established intervention. The success of the strategies to diminish overrequesting of FT4 and tBil tests, and to eliminate redundant tests in hospitalized patients, also needs to be assessed through the use of indicators. Of particular interest is that indicators that measure request ratios of 2 related tests, such as FT4 and TSH, have 2 different applications: identification of inappropriate request and monitoring after intervention.

A very significant issue in implementing any major change is the ability to sustain the intervention. Most—such as educational or administrative strategies—may produce excellent results during the first months of application that, unfortunately, are not maintained over time.[28] However, laboratory professionals have at their disposal excellent information systems that can be utilized to improve requesting in a sustained manner,[17,24,29] and the study findings did show that the results of interventions were maintained over time in every strategy.

Just as process indicators are, outcome indicators must be designed before establishing the strategy. Although the outcome indicators are as straightforward as measuring the decrease of unnecessary treatments,[29] cost savings,[24] or new diagnoses,[17] they are crucial to discovering if the laboratory has become more efficient

and/or is enhancing its contribution to patient management. Indeed, the importance of monitoring after intervention establishment is always important, but it is especially crucial when it comes to correcting the underrequesting of certain tests. In a case like ours, in which we were investigating increased requesting of s-Ca tests and, consequently, increased economic expenses, it was crucial to be able to monitor the strategy's success in such a systematic and detailed manner so that we could decide in a very short period of time whether to stop or continue the intervention. In fact, in the case of s-Ca, a preliminary pilot study—with very carefully chosen outcome indicators—was designed, established, and evaluated before maintaining the intervention over time. The preliminary pilot study strategy ended after 4 months, at which time we reviewed patient medical records to obtain the preliminary results of outcome indicators.[17] In view of the number of HPT cases detected, and the low cost of every case identified, we decided to restart the strategy and maintain it indefinitely. Moreover, the strategy regulates itself. As time passes, there will be fewer patients who haven't had their s-Ca tested in the previous 3 years, and consequently fewer s-Ca tests will be added by means of the strategy.

**FIGURE 3.** tBil Tests That Were Requested and Not Measured but Reported (January 2012–November 2014)[a,b]




tBil indicates total bilirubin.
[a]When tBil test requests were made but not carried out, it was because the patient had a low icteric index value measurement. The guideline for appropriate requests of tBil tests in primary care was established in January 2012.
[b]From January 2010 to November 2011, the number of tBil not measured but reported were 0.

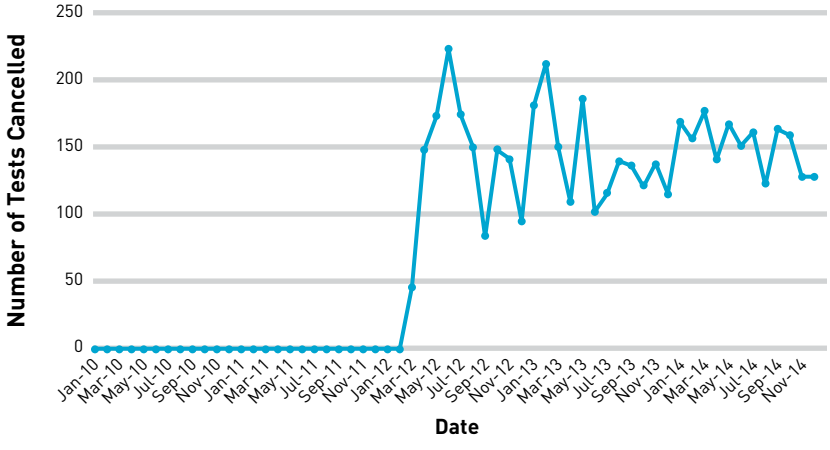
The study results indicate that the strategies do not just enhance laboratory contribution to diagnosis. In fact, through s-Ca strategy, the clinical laboratory becomes the protagonist in diagnosis. It is LIS that, in a continuous way over time, is identifying new cases of HPT. Additionally, the economic savings accrued by correcting laboratory test overrequests will improve the effective use of laboratory resources.

## Limitations

This study has certain limitations. First, the study indicator results, referred to as tests per 1000 inhabitants (residents in the investigators' area), could be considered as research with local importance. These settings might not be appropriate for large testing elsewhere because they were designed for a local population/health service system in Spain. Additionally, in certain environments, a written test request is required for that test to be performed; our s-Ca strategy would not be possible under this requirement.

Another potential limitation is that the strategy we designed for hospitalized patients was to avoid test redundancy due to human errors in manual requesting because the hospitalized patients' medical records are not computerized. It was *not* based on previous studies regarding minimal retesting intervals, defined as the minimum time before a test should be repeated, based on the properties of the test and the clinical situation in which it is used.[30-33]

**FIGURE 4.** Number of Tests Cancelled in Hospitalized Patients (February 2012–November 2014)




[a]The strategy to reach an appropriate request of laboratory tests in hospitalized patients was established in March 2012.
[b]From January 2010 to January 2012, the number of tests cancelled were 0.

Finally, the calculated economic savings of the study may not apply to other countries or settings, since our laboratory belongs to the Public Health Network, where reagent prices are relatively low.

## CONCLUSIONS

The study demonstrates a simple approach to detect inappropriate requests of laboratory tests and to monitor results after appropriate interventions, using process indicators. Indicators that are customized according to the type and to the phase of the strategy are essential to measure the potential impact on patient results. Outcome indicators measure the laboratory's contribution to the diagnosis; to monitoring or preventing diseases; to becoming a protagonist in diagnosis; and to leading the healthcare system towards the most effective uses of its resources.

**Acknowledgments**

The authors would like to express their deep gratitude to José Manuel Ramos Rincón, MD, PhD, for his valuable and constructive suggestions during the review of this paper.

***Author Affiliations:*** Clinical Laboratory, Hospital Universitario de San Juan, San Juan de Alicante (MS, ML-G, EF, JL), Alicante, Spain; Department of Biochemistry and Molecular Pathology, Universidad Miguel Hernández (MS, ML-G, ML-S), Elche, Alicante, Spain; Department of Dermatology, Hospital General Universitario de Alicante (ML-S), Alicante, Spain; Primary Care Center of Muchamiel, Alicante-San Juan Health District (AA), Muchamiel, Alicante, Spain; Department of Radiology, University of Virginia (CL-S), Charlottesville.

***Source of Funding:*** None.

***Author Disclosures:*** The authors report no relationship or financial interest with any entity that would pose a conflict of interest with the subject matter of this article.

***Authorship Information:*** Concept and design (AA, EF, ML-G, JL, CL-S, ML-S, MS); acquisition of data (EF, ML-G, MS); analysis and interpretation of data (EF, ML-G); drafting of the manuscript (AA, EF, ML-G, JL, CL-S, ML-S, MS); critical revision of the manuscript for important intellectual content (AA, EF, ML-G, JL, CL-S, ML-S, MS); statistical analysis (EF, ML-G); and supervision (MS).

***Address Correspondence to:*** Maria Salinas, PhD, Clinical Laboratory, Hospital Universitario de San Juan, Carretera Nacional 322, s/n 03550, San Juan de Alicante, Alicante, Spain. E-mail: salinas_mar@gva.es.

## REFERENCES

1. Hauser RG, Shirts BH. Do we now know what inappropriate laboratory utilization is? an expanded systematic review of laboratory clinical audits. *Am J Clin Pathol*. 2014;141(6):774-783. doi: 10.1309/AJCPX1HIEM4KLGNU.

2. Alonso-Cerezo MC, Martin JS, García Montes MA, de la Iglesia VM. Appropriate utilization of clinical laboratory tests. *Clin Chem Lab Med*. 2009;47(12):1461-1465. doi: 10.1515/CCLM.2009.335.

3. Zhi M, Ding EL, Theisen-Toupal J, Whelan J, Arnaout R. The landscape of inappropriate laboratory testing: a 15-year meta-analysis. *PloS One*. 2013;8(11):e78962. doi: 10.1371/journal.pone.0078962.

4. Fryer AA, Hanna FW. Managing demand for pathology tests: financial imperative or duty of care? *Ann Clin Biochem*. 2009;46(pt 6):435-437. doi: 10.1258/acb.2009.009186.

5. Report of the second phase of the review of NHS Pathology Services in England. The National Archives website. http://webarchive.nationalarchives.gov.uk/20130107105354/http:/www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/@dh/@en/documents/digitalasset/dh_091984.pdf. Published 2008. Accessed July 1, 2015.

6. Janssens PM. Managing the demand for laboratory testing: options and opportunities. *Clin Chim Acta*. 2010;411(21-22):1596-1602. doi: 10.1016/j.cca.2010.07.022.

7. Moloney TW, Rogers DE. Medical technology: a different view of the contentious debate over costs. *N Engl J Med*. 1979;301(26):1413-1419.

8. Rang M. The Ulysses syndrome. *Can Med Assoc J*. 1972;106(2):122-123.

9. Salinas M, López-Garrigós M, Leiva-Salinas C. False positive results: the imaginary invalid syndrome. *Aten Primaria*. 2013;45(10):542. doi: 10.1016/j.aprim.2013.04.010.

10. Salinas M, López-Garrigós M, Uris J. Towards laboratory knowledge, not data, in 70% of clinical decision-making. what "knowledge management" can add to clinical practice? *Clin Chem Lab Med*. 2011;49(8):1389-1390. doi: 10.1515/CCLM.2011.636.

11. Plebani M, Lippi G. Is laboratory medicine a dying profession? blessed are those who have not seen and yet have believed. *Clin Biochem*. 2010;43(12):939-941. doi: 10.1016/j.clinbiochem.2010.05.015.

12. The NHS Atlas of Variation in Diagnostic Services. reducing unwarranted variation to increase value and improve quality. RightCare website. www.rightcare.nhs.uk/downloads/Right_Care_Diagnostics_Atlas_hi-res.pdf. Published November 2013. Accessed July 1, 2015.

13. Smellie WS. Demand management and test request rationalization. *Ann Clin Biochem*. 2012;49(pt 4):323-336. doi: 10.1258/acb.2011.011149.

14. Thomas RE, Croal BL, Ramsay C, Eccles M, Grimshaw J. Effect of enhanced feedback and brief educational reminder messages on laboratory test requesting in primary care: a cluster randomised trial. *Lancet*. 2006;367(9527):1990-1996.

15. Salinas M, López-Garrigós M, Díaz J, et al. Regional variations in test requiring patterns of general practitioners in Spain. *Ups J Med Sci*. 2011;116(4):247-251. doi: 10.3109/03009734.2011.606927.

16. Larsson A, Palmer M, Hultén G, Tryding N. Large differences in laboratory utilisation between hospitals in Sweden. *Clin Chem Lab Med*. 2000;38(5):383-389.

17. Salinas M, López-Garrigós M, Pomares F, et al. Serum calcium (s-Ca), the forgotten test: preliminary results of an appropriateness strategy to detect primary hyperparathyroidism (pHPT). *Bone*. 2013;56(1):73-76. doi: 10.1016/j.bone.2013.05.011.

18. Salinas M, López-Garrigós M, Lugo J, Gutiérrez M, Flors L, Leiva-Salinas C. Diagnostic accuracy of icteric index to detect abnormal total bilirubin values. *J Clin Pathol*. 2012;65(10):928-933.

19. Lundberg GD. Adding outcome as the 10th step in the brain-to-brain laboratory test loop. *Am J Clin Pathol*. 2014;141(6):767-769. doi: 10.1309/AJCP5KSXWTI2DMCC.

20. Larsson A. What can we learn from studies on regional differences in the utilization of laboratory tests? *Ups J Med Sci*. 2011;116(4):225-226. doi: 10.3109/03009734.2011.624281.

21. Franceschini R, Trevisiol C, Dittadi R, Gion M. Tumour markers requesting pattern with regards to different organizational settings in Italy: a survey of hospital laboratories. *Ann Clin Biochem*. 2009;46(pt 4):316-321. doi: 10.1258/acb.2009.008240.

22. Salinas M, López-Garrigós M, Uris J, Leiva-Salinas C. Variation in laboratory tests ordered for patients treated in hospital emergency departments. *Emergencias*. 2014;26:450-458.

23. Salinas M, López-Garrigós M, Flores E, Uris J, Leiva-Salinas C; Pilot Group of the Appropriate Utilization of Laboratory Tests (REDCONLAB) Working Group. Potential over request in anemia laboratory tests in primary care in Spain. *Hematology*. 2015;20(6):368-373. doi: 10.1179/1607845414Y.0000000210.

24. Salinas M, López-Garrigós M, Asencio A, Leiva-Salinas M, Lugo J, Leiva-Salinas C. Laboratory utilization improvement through a computer-aided algorithm developed with general practitioners. *Clin Chem Lab Med*. 2015;53(9):1391-1397. doi: 10.1515/cclm-2014-0762.

25. Salinas M, López-Garrigós M, Uris J, Leiva-Salinas C; Appropriate Utilization of Laboratory Tests (REDCONLAB) Working Group. A study of the differences in the request of glycated hemoglobin in primary care in Spain: a global, significant, and potentially dangerous under-request. *Clin Biochem*. 2014;47(12):1104-1107. doi: 10.1016/j.clinbiochem.2014.04.020.

26. Gion M, Franceschini R, Rosin C, et al; Working Group on Tumour Markers of Italian Society of Clinical Biochemistry and Clinical Molecular Biology (SIBioC). An epidemiology-based model to estimate the rate of inappropriateness of tumor marker requests. *Clin Chem Lab Med*. 2014;52(6):889-897. doi: 10.1515/cclm-2013-0708.

27. Dufour DR, Lott JA, Nolte FS, Gretch DR, Koff RS, Seeff LB. Diagnosis and monitoring of hepatic injury. II. recommendations for use of laboratory tests in screening, diagnosis, and monitoring. *Clin Chem*. 2000;46(12):2050-2068.

28. van Walraven C, Naylor CD. Do we know what inappropriate laboratory utilization is? a systematic review of laboratory clinical audits. *JAMA*. 1998;280(6):550-558.

29. Salinas M, López-Garrigós M, Asencio A, et al. Strategy to improve the request of uric acid in primary care: preliminary results and evaluation through process and outcome appropriateness indicators. *Clin Biochem*. 2014;47(6):467-470. doi: 10.1016/j.clinbiochem.2013.12.025.

30. Kwok J, Jones B. Unnecessary repeat requesting of tests: an audit in a government hospital immunology laboratory. *J Clin Pathol*. 2005;58(5):457-462.

31. van Walraven C, Raymond M. Population-based study of repeat laboratory testing. *Clin Chem*. 2003;49(12):1997-2005.

32. Lang T. National Minimum Re-testing Interval Project: a final report detailing consensus recommendations for minimum re-testing intervals for use in clinical biochemistry. Association for Clinical Biochemistry website. www.acb.org.uk/docs/default-source/committees/scientific/guidelines/acb/acb-mri-recommendations-a4-computer.pdf?sfvrsn=2. Published 2013. Accessed May 25, 2015.

33. Janssens PM, Wasser G. Managing laboratory test ordering through test frequency filtering. *Clin Chem Lab Med*. 2013;51:1207-1215. ■

**eAppendix**

**Table A.** Ways to Identify and Correct Potential Inappropriateness Uses of Laboratory Tests

| |
|---|
| **Evaluate:**<br><br>→ Studies on test-utilization differences among geographical areas<br><br>→ Retrospective studies of test utilization in the LIS patient database<br><br>→ Comparison to guidelines or disease prevalence |
| **Select test and target populations for strategy implementation:**<br><br>→ Based on scientific evidence and on consensus with requesting physicians |
| **Generate the idea:**<br><br>→ If possible based on automatic processes, on the LIS |
| **Pre-design the strategy:**<br><br>→ In consensus with requesting physicians, after LIS retrospective simulation |
| **Create final design:**<br><br>→ Write the procedure: objectives, strategic initiative, indicators, and goals. |
| **Establish strategy** |
| **Monitor through process indicators** |
| **Evaluate through outcome indicators** |
| **Make final decision: continue or stop strategy** |

LIS indicates laboratory information system.

**Table B.** Indicators to Monitor Results After the Establishment of Interventions

| **Process Indicators** |
| --- |
| ✓ Ratios of related test requests |
| ✓ Numbers of added tests |
| ✓ Ratios of test request per highly demanded test |
| ✓ Number of not measured but reported tests |
| ✓ Number of cancelled tests |
| **Outcome Indicators** |
| ✓ Cases detected |
| ✓ Cost per identified case |
| ✓ Cost savings |