BMJ Open Quality

Reducing overutilisation of serum vitamin D testing at a tertiary care centre

Felicia Tai ,[1] Ian Chin-Yee,[2,3] Alan Gob,[3] Vipin Bhayana,[1,2] Angela Rutledge[1,2]

To cite: Tai F, Chin-Yee I, Gob A, *et al*. Reducing overutilisation of serum vitamin D testing at a tertiary care centre. *BMJ Open Quality* 2020;**9**:e000929. doi:10.1136/bmjoq-2020-000929

Received 19 January 2020
Revised 12 February 2020
Accepted 16 February 2020

[1]Department of Pathology and Laboratory Medicine, Western University, London, Ontario, Canada
[2]Department of Pathology and Laboratory Medicine, London Health Sciences Centre and St. Joseph's Health Care London, London, Ontario, Canada
[3]Division of Hematology, Department of Medicine, Schulich School of Medicine and Dentistry, Western University, London, Ontario, Canada

Correspondence to
Dr Angela Rutledge;
angela.rutledge@lhsc.on.ca

ABSTRACT

Introduction Testing of 25-hydroxy (25-OH) vitamin D serum levels has increased drastically in recent years and much of it is considered inappropriate based on current guidelines.

Methods In consultation with our physician groups (experts and frequent orderers), we modified existing guidelines and implemented a rational policy for 25-OH vitamin D testing and 1,25 dihydroxy (1,25 di-OH) vitamin D testing at a tertiary care centre. A computer decision support tool requiring selection of one of five acceptable testing indications was created for each test as part of a computerised physician order entry system.

Results As a result of our intervention, we observed a 27% decrease in the average monthly test volume for 25-OH vitamin D from 504±62 (mean±SD) tests per month to 370±33 (p<0.001). 1,25 di-OH vitamin D testing decreased 58% from 71±18 to 30±10 (p<0.001). The departments ordering the tests were similar during the preintervention and postintervention periods, and further audits, patient chart reviews and individualised physician feedback were required to ensure appropriate ordering of 1,25 di-OH vitamin D. The most common ordering reasons selected were malabsorption/dietary concerns (46%) for 25-OH vitamin D and renal failure (42%) for 1,25 di-OH vitamin D.

Conclusions Limitations of our computer decision support tool include a dependence on an honour system in selecting the testing indication and an inability to limit ordering frequency. Periodic monitoring of test volumes will be required to ensure adherence to guidelines. Despite these limitations, we have improved appropriate utilisation of these tests and reduced costs by approximately $C60 375 per year.

PROBLEM

The Ontario Ministry of Health and Long-Term Care reported that in Ontario approximately 29 000 25-hydroxy (25-OH) vitamin D tests were performed in 2004 and more than 700 000 were performed in 2009, representing an increase of approximately 2500%.[1] Other provinces in Canada,[2 3] as well as other countries[4 5] have also reported dramatic increases in 25-OH vitamin D testing over the past two decades.

The Department of Pathology and Laboratory Medicine is responsible for laboratory testing for several hospitals within the London Health Sciences Centre (LHSC) and St. Joseph's Healthcare London (SJHC) organisations. In total, these hospitals provide tertiary care to a population of approximately 1.5 million in the region of London, Ontario, Canada. At LHSC/SJHC, we began analysing 25-OH vitamin D in-house in January 2009 and since that time, our test volumes had continued to rise from 2130 in 2009 to 6108 in 2017, which is an increase of almost three-fold in 8 years.

We decided to develop and implement a rational policy for 25-OH vitamin D testing at LHSC/SJHC to ensure testing was being limited to appropriate clinical indications. We chose to include 1,25 dihydroxy (1,25 di-OH) vitamin D testing in our initiative because of the higher costs associated with this assay and the concern that it might sometimes be ordered in error when 25-OH vitamin D would be the indicated test.

BACKGROUND

Serum 25-OH vitamin D is a measure of vitamin D sufficiency from diet, endogenous synthesis and supplements. 1,25 di-OH vitamin D is the active form of vitamin D involved in calcium homeostasis. It is formed by 1α-hydroxylase activity, mainly from the kidney, and therefore is most commonly measured to assess sufficiency of kidney function for calcium homeostasis.

The optimal serum level of 25-OH vitamin D is controversial. The Institute of Medicine decided on 50 nmol/L (20 ng/mL) of 25-OH vitamin D as the concentration that would allow at least 97.5% of the population to achieve optimal bone health.[6] However, 75 nmol/L is often considered the threshold for adequacy as supported by several studies showing outcomes such as reduced fracture risk, avoidance of secondary hyperparathyroidism, decreased risk of cardiovascular events, and potentially decreased incidence of colorectal cancer.[7–9] From a study by Rucker *et al*[10] using a Canadian population, 34% of subjects had 25-OH vitamin D insufficiency if 40 nmol/L was used as the cut-off for sufficiency, 61% had insufficiency if 50 nmol/L was used as the cut-off and 97%

of subjects had insufficiency if 80 nmol/L was used as the cut-off. Clearly, a significant proportion of Canadians have 25-OH vitamin D levels considered suboptimal for skeletal health, but the magnitude of the problem is determined by the cut-off that is used.

The northern latitude in Canada results in many Canadians receiving insufficient sun exposure to synthesise adequate 25-OH vitamin D endogenously. Choosing Wisely Canada (CWC) (a national campaign to reduce unnecessary testing and treatments in the Canadian healthcare system), recommends against routine measurement of 25-OH vitamin D in most individuals and instead recommends routine supplementation. Measurement of 25-OH vitamin D levels should be limited to patients who are more likely to require more aggressive therapy, such as patients with osteoporosis, chronic kidney disease, or malabsorption.[11]

Orders for 25-OH vitamin D testing may be considered inappropriate not only due to the indication for testing, but also due to frequency of testing. Osteoporosis Canada[12] recommends waiting 3–4 months after adequate supplementation before repeating the 25-OH vitamin D measurement and not repeating the test once an optimal level (≥75 nmol/L) is achieved. Therefore, both the reason for testing and the frequency of testing were aspects that we felt could potentially be targeted at our site to reduce unnecessary orders for 25-OH vitamin D and 1,25 di-OH vitamin D testing.

There have been efforts to try to restrain the surge in 25-OH vitamin D testing. In 2010, the Ontario Ministry of Health and Long-Term Care limited eligibility for coverage of 25-OH vitamin D testing at private laboratories to patients with osteoporosis/osteopenia, rickets, malabsorption syndromes, or renal disease, or patients on medications that affect vitamin D metabolism.[1] In 2010, British Columbia published a guideline on appropriate 25-OH vitamin D testing and restricted coverage of 25-OH vitamin D testing to orders from specialists or patients less than 19 years old.[3] Based on the efforts in Ontario[1] and British Columbia,[3] Alberta released its guideline for 25-OH vitamin D testing in 2014.[13] Furthermore, in 2015, Alberta implemented a policy whereby coverage for 25-OH vitamin D testing had to be requested by a new provincial requisition form that had one of the following acceptable indications checked off: metabolic bone disease, abnormal blood calcium, malabsorption syndromes, chronic renal disease, or chronic liver disease. This initiative resulted in a 91% decrease in testing.[14] In all of these situations, patients could pay out of pocket for the test if they did not meet the provincial testing criteria.

Within LHSC/SJHC, the global hospital budget covers the cost of all 25-OH vitamin D tests performed on-site regardless of whether or not the patient would qualify to have the test covered by the Ontario Health Insurance Plan at a private laboratory in Ontario. We undertook a quality improvement project at LHSC/SJHC to restrict testing for 25-OH vitamin D or 1,25 di-OH vitamin D to clinically appropriate indications, determined based on published guidelines and consultation with local clinicians. We also aimed to ensure ordering of these tests was not occurring more often than recommended for each patient.

Design and strategy

We (an undergraduate honours thesis student and a clinical biochemist) began by compiling lists of appropriate testing indications for LHSC/SJHC by reviewing existing Canadian guidelines[1 13 14] on vitamin D testing. We then sought feedback on our compiled testing indications from 13 local physicians, in specialties such as endocrinology, gastroenterology, nephrology and metabolics, who we considered to be experts in their fields. Once we had received and incorporated their input, we sought feedback from 77 other physicians who had ordered more than 20 tests for either 25-OH vitamin D or 1,25 di-OH vitamin D during the 2-year preintervention period. Lastly, we also sought feedback from a group of dieticians. All of this feedback was requested via email from the head of the laboratory medicine programme.

As suggested by the dieticians, 25-OH vitamin D testing indications were expanded to include patients on specialised diets (eg, total parenteral nutrition) or patients at high risk for insufficiency despite supplementation. Paediatric endocrinology concern (eg, vitamin D-dependent rickets) was added as a 1,25 di-OH vitamin D testing indication at the advice of one of our expert paediatric endocrinologists. Suggestions to allow 25-OH vitamin D testing for patients presenting with chronic fatigue were not supported by the literature and therefore not included as an acceptable indication.

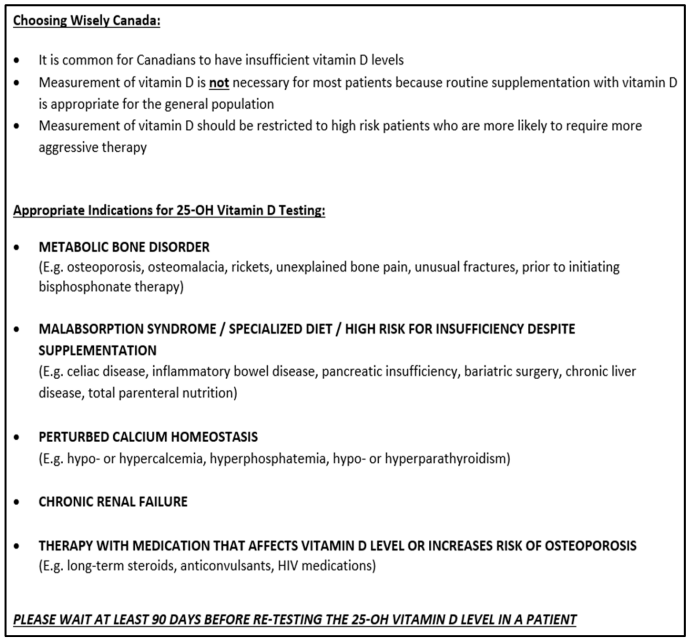
One week prior to implementation of our ordering restrictions for 25-OH vitamin D or 1,25 di-OH vitamin D testing, all LHSC/SJHC physicians were informed by memo from the Pathology and Laboratory Medicine Department.

On January 15, 2018, one of our laboratory information system technologists implemented an informational pop-up window (figure 1A) in the computerised physician order entry (CPOE) system within Cerner Millennium, the hospital information system, that appears any time an order for 25-OH vitamin D testing is entered. One of five appropriate indications for testing (figure 1B) must be selected before the order can proceed. The information from the pop-up window shown in figure 1A was also associated with the orderable as a reference in the CPOE system in case anyone needed more information to understand the five indications.

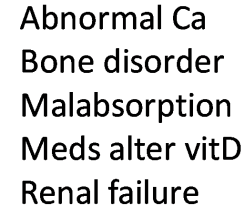
A similar strategy was adopted for 1,25 di-OH vitamin D testing, requiring one of five appropriate indications to be selected in the CPOE system for the order to proceed (figure 1C). Additional information was included with the orderable as a reference (figure 1D).

The changes to the CPOE system were relatively simple for the technologist to make and were authorised by the clinical biochemist responsible for these two tests, with

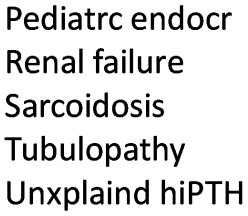
A)



B)



C)



D)

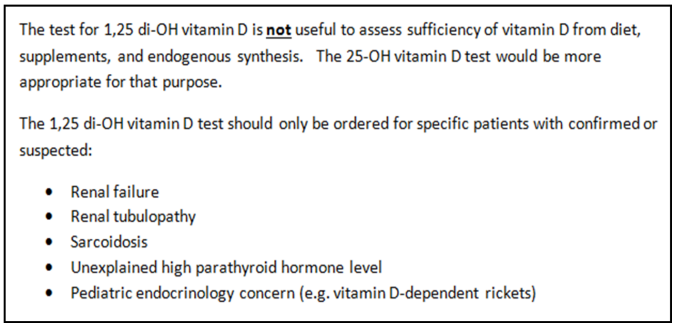


Figure 1 LHSC/SJHC testing policy for 25-OH vitamin D and 1,25 di-OH vitamin D, implemented within the CPOE system in Cerner Millennium. (A) Information pop-up window that appears when an order for 25-OH vitamin D is entered. This information is also associated with the orderable as reference text that can be consulted if someone needs more details before selecting the reason for ordering the test. (B) The drop-down menu of appropriate indications for testing that must be selected from to allow the order for 25-OH vitamin D testing to proceed. The choices were limited to 15 characters by Cerner Millennium. (C) The drop-down menu of appropriate indications for testing that must be selected from to allow the order for 1,25 di-OH vitamin D testing to proceed. The choices were limited to 15 characters by Cerner Millennium. (D) Information associated with the 1,25 di-OH vitamin D orderable as reference text that can be consulted if someone needs more details before selecting the reason for ordering the test. CPOE, computerised physician order entry; LHSC, London Health Sciences Centre; SJHC, St. Joseph's Health Care London; 25-OH, 25-hydroxy; 1,25 di-OH, 1,25 dihydroxy.

the support of the head of the clinical biochemistry division and the head of the laboratory medicine programme.

An exception to our intervention was required to accommodate orders for 25-OH vitamin D or 1,25 di-OH vitamin D testing submitted on paper requisition forms (and therefore bypassing CPOE) from outpatient clinics or as part of funded research projects. For these patients, we allowed laboratory staff to order 25-OH vitamin D or 1,25 di-OH vitamin D testing using lab-specific orderables that do not require entry of testing indications. This prevents the burden on lab staff from having to seek appropriate testing indications for tests that were not ordered within the CPOE system.

Figure 2 provides a summary of the steps included in the design of our project to restrict orders for 25-OH vitamin D or 1,25 di-OH vitamin D testing to appropriate indications.

Measurement

25-OH vitamin D testing in serum is performed at LHSC/SJHC by a competitive chemiluminescent immunoassay on a DiaSorin Liaison XL analyser. The reference intervals used for the test are: deficiency: <25 nmol/L; insufficiency: 25–74 nmol/L; sufficiency: 75–250 nmol/L; and toxicity: >250 nmol/L. 1,25 Di-OH vitamin D testing is performed at LHSC/SJHC on the same analyser by a non-competitive chemiluminescent immunoassay. The reference interval used is 60–208 pmol/L.

We retrospectively audited all 25-OH vitamin D and 1,25 di-OH vitamin D tests performed at LHSC/SJHC between January 1, 2016 and December 31, 2017 to collect our historical baseline data. During this time period there were 12 102 25-OH vitamin D tests performed for an average of about 504 tests per month and 1706 1,25 di-OH vitamin D tests performed for an average of about 71 tests per month.

Orders for 25-OH vitamin D and 1,25 di-OH vitamin D were also audited from January 1, 2018 to July 31, 2018 to allow us to see the effects of our intervention, which was implemented on January 15, 2018.

Excel's PivotTable tool was used to analyse the audited data to determine which physicians and departments ordered the most tests and how frequently the tests were ordered. Average monthly test volumes were calculated and the per cent difference in average monthly test volumes postintervention compared with preintervention were determined. The month of January 2018 was omitted from the statistical analysis (unpaired two-tailed t-tests using Excel) since our intervention was implemented in the middle of the month. QI Macros SPC software was used to plot the statistical process control charts.

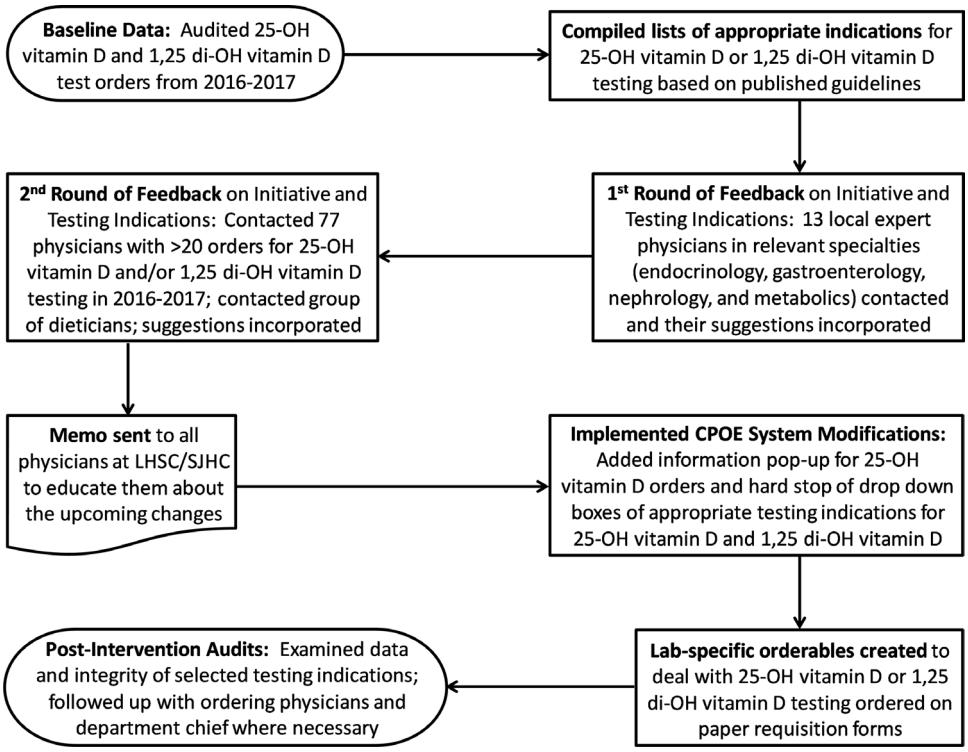


Figure 2 Summary of steps taken to ensure appropriate ordering of 25-OH vitamin D and 1,25 di-OH vitamin D tests at LHSC/SJHC. CPOE, computerised physician order entry; LHSC, London Health Sciences Centre; SJHC, St. Joseph's Health Care London; 25-OH, 25-hydroxy; 1,25 di-OH, 1,25 dihydroxy.

For patients who had 25-OH vitamin D retested during a 6-month period, a χ^2 test was used to compare the proportion of patients with a change in category of result based on whether the retest had occurred before 90 days or after 90 days. χ^2 tests were also used to determine whether there were any significant changes in the percentage of patients falling into each 25-OH vitamin D or 1,25 di-OH vitamin D result category as a result of the intervention.

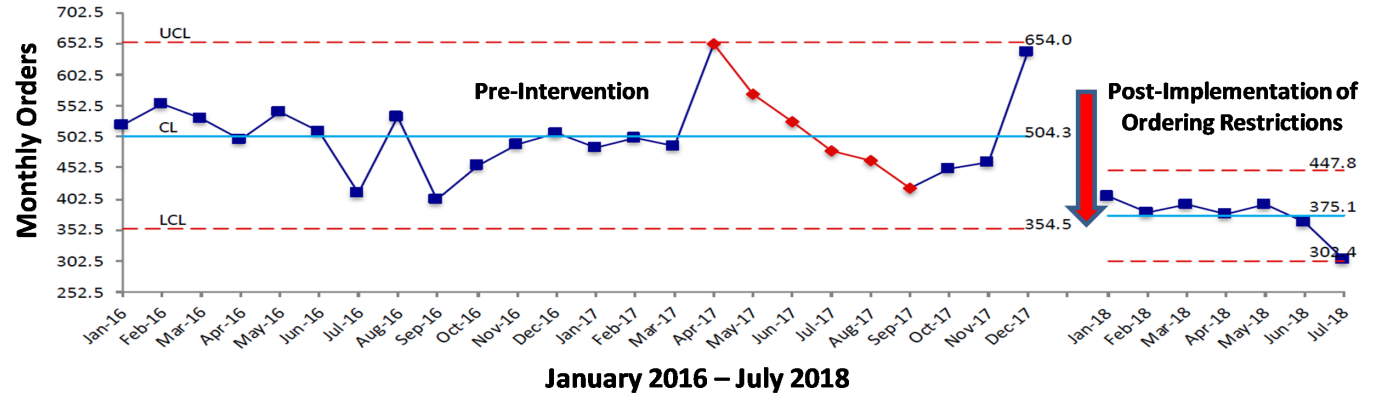
RESULTS

In general, the expert physicians, frequent orderers and dieticians who responded to our request for input had comments supportive of the proposed initiative to limit 25-OH vitamin D and 1,25 di-OH vitamin D testing to specific patient populations.

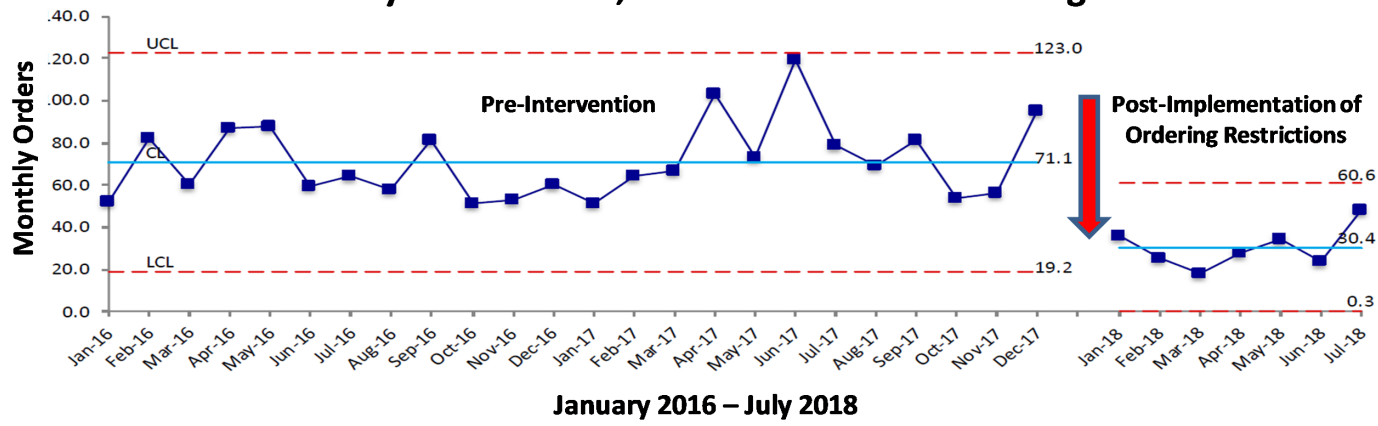
There were significant decreases in monthly test volumes for 25-OH vitamin D and 1,25 di-OH vitamin D during the time period when the restrictions were implemented (figure 3A,B). Figure 3C shows that the average monthly test volume decreased 27% from 504±62 to 370±33 ($p<0.001$) for 25-OH vitamin D and 58% from 71±18 to 30±10 ($p<0.001$) for 1,25 di-OH vitamin D. Statistical process control demonstrated special cause variation in January 2018 for both 25-OH vitamin D (figure 3A) and 1,25 di-OH vitamin D (figure 3B), which was when our intervention occurred. After this point, only common cause variation was observed, indicating a stable lower level of ordering. Interestingly, there was a spike in 25-OH vitamin D ordering in April 2017 that was outside the control limits and then five consecutive decreases in ordering between May and September 2017. These changes suggest that there may have been a special event or outside factor affecting 25-OH vitamin D ordering during these periods. We were unable to identify retrospectively any factor that would have influenced ordering of 25-OH vitamin D testing during these anomalous time periods. The departments ordering the most tests before and after our interventions were compared, as shown in table 1. For 25-OH vitamin D, the top three ordering specialties, both before and after, were endocrinology, paediatric gastroenterology and gastroenterology. For 1,25 di-OH vitamin D, the top four ordering specialities before the intervention were gastroenterology, paediatric medicine, paediatric nephrology and nephrology. After the intervention, the top four ordering specialties remained the same for 1,25 di-OH vitamin D, but the order had changed.

We also examined the percentage of patients for whom both 25-OH vitamin D and 1,25 di-OH vitamin D testing or only one of the tests had been ordered, as shown in figure 4. Prior to the intervention, the percentage of patients with only 25-OH vitamin testing ordered, only 1,25 di-OH vitamin D testing ordered, or both tests ordered were 85%, 9% and 6%, respectively, compared with 92%, 4% and 4% after the intervention. The most notable change in ordering of both tests on a patient occurred with the gastroenterology department. Prior to the intervention, the gastroenterology department was the top specialty ordering both 25-OH vitamin D and 1,25 di-OH vitamin D testing on a patient and were responsible

A)



B)



C)

Period	25-OH Vitamin D		1,25 Di-OH Vitamin D	
	Average Monthly Test Volume (SD)	P-Value Compared to Pre-Intervention Period	Average Monthly Test Volume (SD)	P-Value Compared to Pre-Intervention Period
Pre-Intervention	504 (62)		71 (18)	
Post-Implementation of Ordering Restrictions	370 (33)	< 0.001	30 (10)	< 0.001

Figure 3 Test volumes for 25-OH vitamin D and 1,25 di-OH vitamin D during the preintervention period (January 1, 2016 to December 31, 2017) and the postimplementation of ordering restrictions period (February 1, 2018 to July 31, 2018). (A) Monthly test volumes for 25-OH Vitamin D. (B) Monthly test volumes for 1,25 di-OH vitamin D. (C) Average monthly test volumes and p values according to unpaired two-tailed t-tests. January 2018 was not included in the statistical analysis of monthly test volumes since the intervention occurred in January 15, 2018, in the middle of the month. 25-OH, 25-hydroxy; 1,25 di-OH, 1,25 dihydroxy.

Table 1 The three medical specialties at LHSC/SJHC ordering the most 25-OH vitamin D or 1,25 di-OH vitamin D testing, both prior to and following the intervention. The percentage of the total tests ordered during that period (pre-intervention: January 1, 2016 to December 31, 2017; post-implementation of ordering restrictions: February 1, 2018 to July 31, 2018) that came from each department are shown in brackets.

25-OH vitamin D		1,25 Di-OH vitamin D	
Preintervention	Postimplementation of ordering restrictions	Preintervention	Postimplementation of ordering restrictions
Endocrinology (12%)	Endocrinology (15%)	Gastroenterology (31%)	Gastroenterology (13%)
Paediatric gastroenterology (12%)	Paediatric gastroenterology (13%)	Paediatric medicine (8%)	Nephrology (8%)
Gastroenterology (6%)	Gastroenterology (11%)	Paediatric nephrology (5%)	Paediatric nephrology (8%)

1,25 di-OH, 1,25 dihydroxy; LHSC, London Health Sciences Centre; 25-OH, 25-hydroxy; SJHC, St. Joseph's Health Care London.

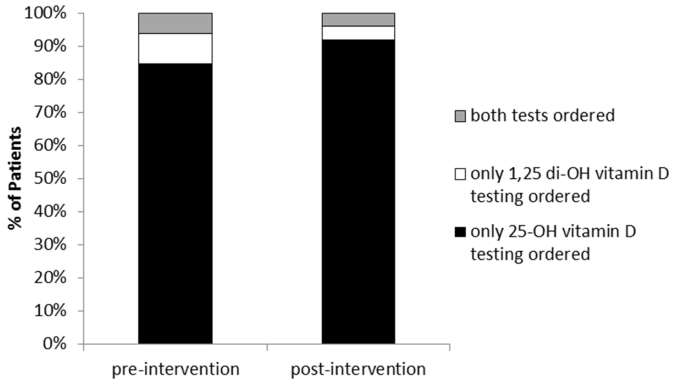


Figure 4 Percentage of patients with orders for 25-OH vitamin D testing only (black bars), 1,25 di-OH vitamin D testing only (white bars), or both tests (grey bars), both in the preintervention period (January 1, 2016 to December 31, 2017) and the postintervention period (February 1, 2018 to July 31, 2018). 25-OH, 25-hydroxy; 1,25 di-OH, 1,25 dihydroxy.

for 16% of the combined orders. After the implementation, gastroenterology was ordering 3% of the combined orders and had dropped to the eighth highest specialty.

Postintervention (between February 1, 2018 and July 31, 2018), 177 patients out of 1967 total patients (9%) had 25-OH vitamin D retested during the audited period. Out of the 248 repeat tests, 199 tests were performed prior to 90 days (80%). The average number of days prior to retesting was 52±38. To make the data more comparable, we examined the 6-month preimplementation period between February 1, 2017 and July 31, 2017. We identified that 263 patients out of 2853 total patients (9%) had 25-OH vitamin D retested during this period. Out of the 365 repeat tests, 287 were performed prior to 90 days (79%), similar to the postintervention period. The average number of days prior to retesting was 55±41. The three departments ordering retesting of 25-OH vitamin D prior to 90 days the most often were also very similar before and after the intervention: paediatric gastroenterology (pre: 37% of all 25-OH vitamin D retesting prior to 90 days; post: 45%), paediatric nephrology (pre: 13%, post: 12%) and paediatric medicine: (pre: 7%, post: 6%).

As shown in figure 5A, there was more likely to be a change in category of 25-OH vitamin D result (deficiency: <25 nmol/L; insufficiency: 25–74 nmol/L; sufficiency: 75–250 nmol/L; and toxicity: >250 nmol/L) if the length of time before retesting was 90 days or more than if the length of time was less than 90 days ($p<0.01$).

In terms of the category of 25-OH vitamin D (deficiency, insufficiency, sufficiency, or toxicity) or 1,25 di-OH vitamin D (low, normal, or high) result, there were no significant differences in the percentage of patients falling into each category during the postintervention period compared with the preintervention period (figure 5B,C, respectively). We did observe that during the summer months, there was a trend towards more sufficiency and less insufficiency of 25-OH vitamin D levels both before and after the intervention, as expected (data not shown).

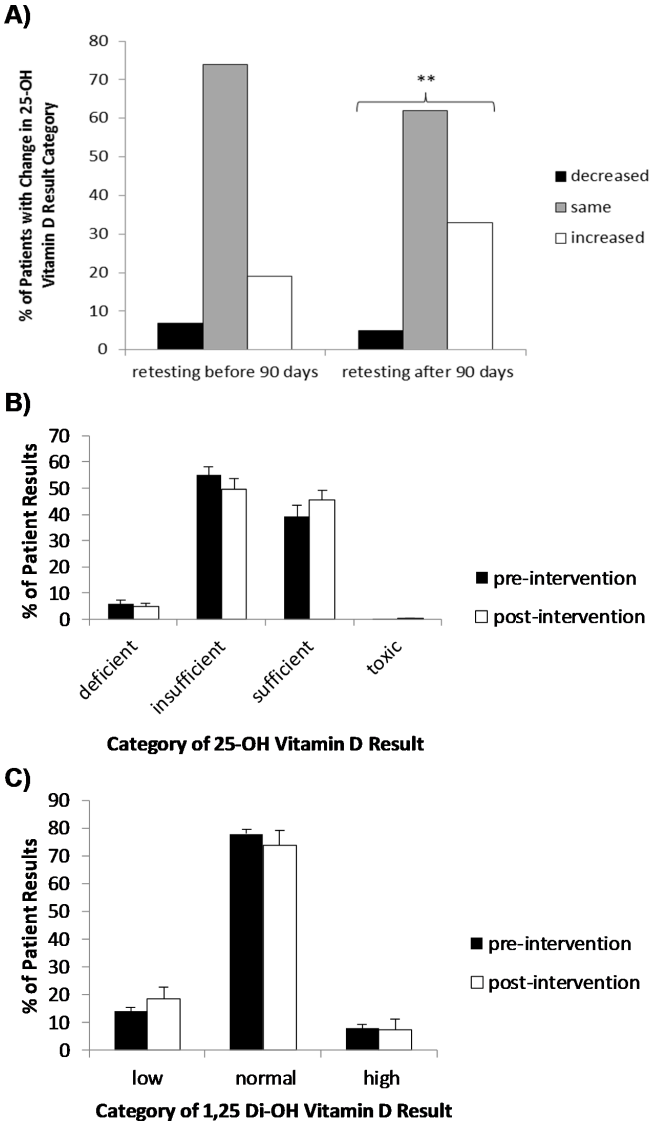


Figure 5 (A) Percentage of patients with 25-OH vitamin D retested before or after 90 days who had a change or no change in category of result (deficiency: <25 nmol/L; insufficiency: 25–74 nmol/L; sufficiency: 75–250 nmol/L; and toxicity: >250 nmol/L). **P < 0.01 for retesting after 90 days or more compared with retesting before 90 days by two-tailed χ^2 test. (B) The percentage of patient 25-OH vitamin D results falling into each category during the preintervention and postintervention periods (monthly mean±SD). (C) The percentage of patient 1,25 di-OH vitamin D results falling into each category (low: <60 pmol/L; normal: 60–208 pmol/L; and high: >208 pmol/L) during the preintervention and postintervention periods (monthly mean±SD). 25-OH, 25-hydroxy; 1,25 di-OH, 1,25 dihydroxy.

The reasons for ordering either 25-OH vitamin D or 1,25 di-OH vitamin D testing, which were required to be entered in the CPOE system as a result of our intervention, are summarised in figure 6. The top two reasons for 25-OH vitamin D were malabsorption/dietary concerns (46% of all reasons) and metabolic bone disorders (30%). The top two reasons for 1,25 di-OH vitamin D were renal failure (42%) and unexplained high parathyroid hormone level (28%). We found that 7% of 25-OH

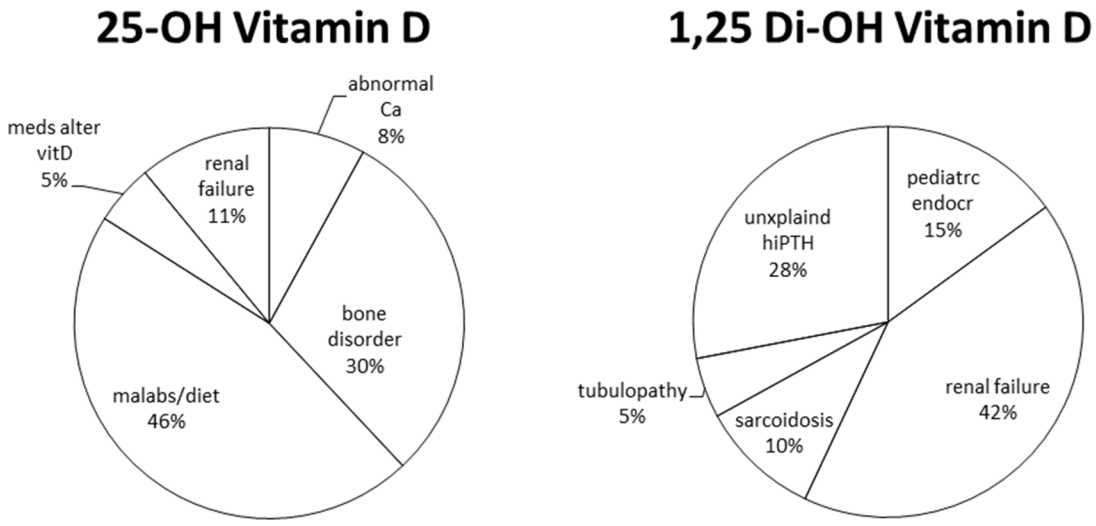


Figure 6 Reasons for ordering 25-OH vitamin D or 1,25 di-OH vitamin D testing that were given following implementation of the ordering restrictions. PTH, parathyroid hormone; 25-OH, 25-hydroxy; 1,25 di-OH, 1,25 dihydroxy.

vitamin D orders and 2% of 1,25 di-OH vitamin D orders were entered using the lab-specific orderables for paper requisition forms, which are exempt from giving a reason for ordering.

The estimated cost of 25-OH vitamin D testing, including reagents, supplies, instrument costs and labour, is estimated to be $C18.38 per test. At an average monthly test volume of 504 prior to the intervention, the monthly costs would be approximately $C9265, compared with approximately $C6800 per month for 370 tests after the intervention. Over the course of a year, the savings in 25-OH vitamin D costs would be approximately $C29 555. The estimated cost of 1,25 di-OH vitamin D testing is estimated to be $C62.64 per test. At an average monthly test volume of 71 prior to the intervention, the monthly costs would be approximately $C4445, compared with approximately $C1880 per month for 30 tests after the intervention. Over the course of a year, the savings in 1,25 di-OH vitamin D costs would be approximately $C30 820. The combined yearly savings for 25-OH vitamin D and 1,25 di-OH vitamin D testing as a result of the intervention are estimated to be approximately $C60 375. This quality improvement project incurred no additional costs to implement as it fell under the laboratory strategic plan to implement choosing wisely laboratory utilisation initiatives.

DISCUSSION

As a result of our initiative, we observed a 27% decrease in the average monthly test volume for 25-OH vitamin D and a 58% decrease in the average monthly test volume for 1,25 di-OH vitamin D. The decrease in 25-OH vitamin D ordering is lower than that observed in the province of Alberta (91%) by creating a new policy and requiring a specific requisition form with an acceptable testing indication checked off to qualify for coverage by the provincial health insurance plan.[14] Our decrease in 25-OH vitamin D ordering is also smaller than that observed by Felcher *et al*[15] in an integrated group-model of healthcare in the Pacific Northwest of the United States. They removed all ordering shortcuts for 25-OH vitamin D testing from the electronic health record and implemented a clinical decision support tool requiring the physician to acknowledge a new guideline of appropriate indications for 25-OH vitamin D testing each time the test was ordered. As a result, a 67% decrease in the number of 25-OH vitamin D tests ordered was observed and the proportion of inappropriate indications for testing decreased from 44% to 30%. Since LHSC/SJHC offers tertiary care predominantly to hospitalised patients or patients in subspecialty clinics, we recognised that our patients may be more likely than the general population to have appropriate indications for 25-OH vitamin D testing, and therefore we expected the magnitude of the decrease in ordering as a result of our intervention to be smaller than that observed for some other patient environments. In-hospital testing covered by the global budget also does not have the additional financial disincentive for physicians and patients ordering testing outside of guideline recommendations. However, we also tackled 1,25 di-OH vitamin D ordering at the same time as 25-OH vitamin D ordering, which the other studies did not.

Our intervention is estimated to save approximately $C60 375 per year for 25-OH vitamin D and 1,25 di-OH vitamin D testing combined. Since there are often cuts to the laboratory budget, reducing the investment in inappropriate tests may allow the laboratory to continue to perform other tests that add more value. The reduction in technologist time and financial resources being spent on inappropriate 25-OH vitamin D and 1,25 di-OH vitamin D testing may also allow new tests to be implemented. Although this may be considered a modest amount of cost savings, as we see with most laboratory testing, the true cost savings include downstream interventions, additional diagnostic testing and inappropriate therapeutic decisions.

One of the aspects of the preintervention data that stood out to us as likely being inappropriate was the high volume of 1,25 di-OH vitamin D tests ordered in the gastroenterology department. As a result of our intervention, we observed a trend toward increased ordering of 25-OH vitamin D testing and decreased ordering of 1,25 di-OH vitamin D testing by the gastroenterology department. This was observed in terms of the percentage of tests ordered, although the hierarchical placement did not change relative to other departments (table 1). There was also a trend toward decreased combined ordering of 1,25 di-OH vitamin D and 25-OH vitamin D testing. This may indicate that our intervention was able to change the practices of some gastroenterologists. However, it was very alarming to us that the gastroenterology department remained the specialty ordering the highest volume of 1,25 di-OH vitamin D testing during the 6 months after implementation of the ordering restrictions. Auditing of the indications for 1,25 di-OH vitamin D testing selected by the gastroenterology department, followed by patient chart reviews, indicated that the selected reasons were untrue. We therefore followed up with the chief of the gastroenterology department and the individual ordering physicians with education about appropriate 1,25 di-OH vitamin D testing indications. There were misconceptions within the gastroenterology department about which form of vitamin D would be appropriate to measure in patients with malabsorption. Since this individualised attention and education, ordering practice has improved.

Lessons and limitations

One of the strengths of our approach was that during the planning stage we engaged healthcare providers who would be impacted by this quality improvement project. Rather than simply adopting published guidelines, this allowed local concerns with the proposed testing indications to be addressed pre-emptively. We believe that our process also increased acceptance of the changes by practitioners because they felt they had been consulted and because they recognised that local experts had agreed with the restrictions. While the time period between receiving feedback from healthcare providers and implementing our ordering restrictions was brief (less than 2 months), we did not observe a decrease in ordering of 25-OH vitamin D or 1,25 di-OH vitamin D testing as a result of the consultation process. This suggests that if our only intervention had been a list of appropriate testing indications as an educational memo or an educational pop-up in the CPOE system, there would have been very little impact. Our previous experience with restricting combined erythrocyte sedimentation rate and C-reactive protein testing also demonstrated minimal impact of email memos or e-casts in changing physician behaviour.[16] The fact that we made selection of the testing indication mandatory at the time of order entry (ie, a hard stop) is likely the major reason that our intervention had an impact.

One of the limitations of our method is that we did not include any specific balancing measures. While we believe that our approach targeted inappropriate testing of 25-OH vitamin D or 1,25 di-OH vitamin D rather than reducing appropriate testing, we cannot prove it. We also cannot be sure there were no unintended consequences. However, our project was designed to ensure that appropriate reasons for 25-OH vitamin D or 1,25 di-OH vitamin D testing would be allowed. We consulted other published guidelines when preparing our lists of acceptable testing indications and sought input from a large number of individuals (physician experts, frequent orderers and dieticians).

There were no significant differences in the percentage of 25-OH vitamin D results falling into each category as a result of our intervention (figure 5B), but because the total amount of 25-OH vitamin D testing decreased, there were fewer patients in the deficient or insufficient range who would have received testing. However, for 25-OH vitamin D, it is well-recognised that much of the Canadian population has suboptimal levels and CWC recommends routine supplementation over routine testing.[11] There is also a variety of evidence to suggest that even when 25-OH vitamin D is measured and found to be low, it often does not result in improvement in the patient's 25-OH vitamin D level. Wei *et al*[17] observed that in patients who had 25-OH vitamin D measured and then re-measured 300–400 days later at a healthcare centre in California, only 8% more patients had 25-OH vitamin D levels considered sufficient (≥75 nmol/L) approximately 1 year after the initial testing. Similarly, Quaggiotto *et al*[5] noted that while 25-OH vitamin D testing increased 730% between 2001 and 2010 in Australia, no significant difference in the rate of deficiency (≤50 nmol/L) or insufficiency (51–75 nmol/L) was observed over this period. Thus, there is little evidence that measurement of the 25-OH vitamin D level results in improvement of the patient's level. We do not have any information about the rates of vitamin D supplementation prior to or following our intervention.

Similarly, for 1,25 di-OH vitamin D, we did not have any balancing measures to ensure we did not decrease appropriate testing. We also did not observe any change in the percentage of results falling into the low, normal and high categories as a result of our intervention (figure 5C). Because the total number of 1,25 di-OH vitamin D tests decreased, there would have been fewer patients with low or high 1,25 di-OH vitamin D levels who would have received testing due to our efforts. The consequences of this are not clear. We do not know what percentage of low or high 1,25 di-OH vitamin D results were acted on before or after the intervention. We know that we were able to decrease 1,25 di-OH vitamin D test orders by the gastroenterology department, which were meant to be 25-OH vitamin D tests related to malabsorption. Thus, there were inappropriate orders dealt with as a result of our intervention. We also took every effort in the study design to ensure that appropriate orders for 1,25 di-OH vitamin D testing would be permitted.

Another limitation of our intervention is that while it forces the healthcare provider to enter a reason for testing from a limited list, it does not ensure the accuracy of the indication or prevent the provider from choosing a false indication to circumvent the restrictions. Specifically, by auditing the data and performing chart reviews for the individual patients we did identify some healthcare providers who selected testing indications that did not apply to their patients, largely based on misunderstanding of the differences between the 25-OH vitamin D and 1,25 di-OH vitamin D tests. Furthermore, many patients being assessed in clinic have electronic orders placed at a physician's written or verbal request by clerical staff unfamiliar with the specific indications in the drop-down lists, who may then randomly select reasons. Because of the time involved in identifying abuses of the system, only anomalies that stand out blatantly are likely to be investigated and addressed.

An additional limitation of our approach was that we did not have the ability within our CPOE system, Cerner Millennium, to easily restrict ordering frequency of 25-OH vitamin D testing to a specified time period such as 3 months. We could only include the request not to reorder 25-OH vitamin D testing within 3 months in our information pop-up. Clearly this did not have an effect on testing frequency, with approximately 80% of the retests within 6 months occurring prior to 90 days in both the preintervention and postintervention periods. Many of these appeared to be monthly tests in paediatric patients. Efforts are being made to develop some of the tools required to limit test frequency in Cerner Millennium and we are currently piloting such a project with restrictions on haemoglobin A1c ordering frequency. Alternatively, we could institute manual cancelling by the laboratory technologists of tests ordered too frequently, but it would be more ideal to have the process automated and to occur before the blood draw.

One potential confounding factor was a simultaneous quality improvement project to reduce inappropriate ordering of 25-OH vitamin D and thyroid-stimulating hormone (TSH) testing on admission of patients to inpatient rehabilitation units at one LHSC/SJHC site. This initiative involved in-person education of clinical team leaders and key stakeholders of the clinical practice guidelines on the subject and the scope of the issue.[18] Departments that would have been affected by this project were responsible for 12% of all LHSC/SJHC 25-OH vitamin D orders prior to our intervention and 1% of 25-OH vitamin D orders postimplementation of our intervention. After their intervention, which coincided with ours, a 96% decrease in 25-OH vitamin D ordering on admission to rehabilitation units was observed, compared with a 47% decrease for TSH. It is difficult to estimate the magnitude of the impact the two projects have on each other but the efforts were likely synergistic. At most, if our intervention had no impact in the inpatient rehabilitation units, the other project could have contributed to a decrease of 11% out of the total 27% decrease in 25-OH vitamin D ordering that was observed. It is expected that there was no impact on 1,25 di-OH vitamin D ordering.

Future directions

Despite our intervention functioning as a hard stop, because it relies on an honour system, it will be necessary to monitor test volumes during the control phase of this project. If there is an increase in ordering observed, it will be necessary to delve into where the increase is coming from and to address it accordingly.

Our study was not effective at limiting testing frequency for 25-OH vitamin D to 3 months, as suggested by Osteoporosis Canada.[12] Three to 4 months is the period of time required to obtain a plateau in 25-OH vitamin D concentration following a change in vitamin D supplementation.[19] Our data showed, not surprisingly, that there is more likely to be a change in 25-OH vitamin D result if the interval before retesting is longer than 3 months (figure 5A). This may be an area to focus on in the future as more tools to enforce testing frequency become available.

Acknowledgements We would like to thank Paul Patrick, laboratory information system technologist, for his assistance with implementing the changes.

Contributors FT and AR contributed to project design, implementation, data analysis and manuscript preparation. IC-Y and VB contributed to project design, implementation and manuscript preparation. AG advised on quality improvement methodology and constructed and interpreted the SPC charts.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient consent for publication Not required.

Ethics approval This project was a quality improvement initiative and, therefore, according to local policy did not require formal approval by the research ethics board.

Provenance and peer review Not commissioned; internally peer reviewed.

Data availability statement Data are available upon request.

ORCID iD

Felicia Tai http://orcid.org/0000-0003-0652-6946

REFERENCES

1 Ministry of Health and Long-Term Care [Internet]. Ontario: Ministry of Health and Long-Term Care; c2010 [cited 2018 Sep 11]. Understanding changes to OHIP coverage of vitamin D testing. Available: http://www.health.gov.on.ca/en/public/programs/ohip/changes/docs/MOH_Vitamin_D_fact_sheet.pdf

2 Rodd C, Sokoro A, Lix LM, *et al*. Increased rates of 25-hydroxy vitamin D testing: dissecting a modern epidemic. *Clin Biochem* 2018;59:56–61.

3 BCGuidelines.ca [Internet]. Victoria: Guidelines and Protocols Advisory Committee; c2010-2013 [cited 2018 Sep 12]. Vitamin D testing protocol. Available: https://www2.gov.bc.ca/gov/content/health/practitioner-professional-resources/bc-guidelines/vitamin-d-testing

4 Woodford HJ, Barrett S, Pattman S. Vitamin D: too much testing and treating? *Clin Med* 2018;18:196–200.

5 Quaggiotto P, Tran H, Bhanugopan M. Vitamin D deficiency remains prevalent despite increased laboratory testing in New South Wales, Australia. *Singapore Med J* 2014;55:271–80.
6 Aloia JF. Clinical review: the 2011 report on dietary reference intake for vitamin D: where do we go from here? *J Clin Endocrinol Metab* 2011;96:2987–96.
7 Vieth R, Bischoff-Ferrari H, Boucher BJ, *et al*. The urgent need to recommend an intake of vitamin D that is effective. *Am J Clin Nutr* 2007;85:649–50.
8 Vieth R, Ladak Y, Walfish PG. Age-related changes in the 25-hydroxyvitamin D versus parathyroid hormone relationship suggest a different reason why older adults require more vitamin D. *J Clin Endocrinol Metab* 2003;88:185–91.
9 Souberbielle J-C, Body J-J, Lappe JM, *et al*. Vitamin D and musculoskeletal health, cardiovascular disease, autoimmunity and cancer: recommendations for clinical practice. *Autoimmun Rev* 2010;9:709–15.
10 Rucker D, Allan JA, Fick GH, *et al*. Vitamin D insufficiency in a population of healthy western Canadians. CMAJ.2002;166(12):1517-1524. Erratum in. *CMAJ* 2002;167:850.
11 Choosing Wisely Canada [Internet]. Toronto: choosing wisely Canada. [cited 2018 Sep 11], c2018. Available: https://choosingwiselycanada.org/
12 Papaioannou A, Morin S, Cheung AM, *et al*. For the scientific Advisory Council of osteoporosis Canada. 2010 clinical practice guidelines for the diagnosis and management of osteoporosis in Canada: summary. *CMAJ* 2010;182:1864–73.
13 Toward Optimized Practice (TOP) Working Group for Vitamin D [Internet]. Edmonton: Toward Optimized Practice; c2014 [cited 2018 Sept 12]. Guideline for vitamin D testing and supplementation in adults. Available: http://www.topalbertadoctors.org/download/1304/Vitamin%20D%20Testing%20and%20Supplementation.pdf?_20180912191923
14 Naugler C, Hemmelgarn B, Quan H, *et al*. Implementation of an intervention to reduce population-based screening for vitamin D deficiency: a cross-sectional study. *CMAJ Open* 2017;5:E36–9.
15 Felcher AH, Gold R, Mosen DM, *et al*. Decrease in unnecessary vitamin D testing using clinical decision support tools: making it harder to do the wrong thing. *J Am Med Inform Assoc* 2017;24:776–80.
16 Gottheil S, Khemani E, Copley K, *et al*. Reducing inappropriate ESR testing with computerized clinical decision support. *BMJ Qual Improv Rep* 2016;5:u211376.w4582.
17 Wei M, Yu R, Deutsch SC. Insignificant medium-term vitamin D status change after 25-hydroxyvitamin D testing in a large managed care population. *PLoS One* 2014;9:e105571.
18 Bateman EA, Gob A, Chin-Yee I, *et al*. Reducing waste: a guidelines-based approach to reducing inappropriate vitamin D and TSH testing in the inpatient rehabilitation setting. *BMJ Open Qual* 2019;8:e000674.
19 Heaney RP, Davies KM, Chen TC, *et al*. Human serum 25-hydroxycholecalciferol response to extended oral dosing with cholecalciferol. *Am J Clin Nutr* 2003;77:204–10.