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Evaluating practice variance among family physicians to identify targets for laboratory utilization management

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ABSTRACT

Background: There is widespread variation in testing practice among practitioners, however there has been no objective way to pinpoint target tests for utilization management. We propose to take advantage of inter-physician variance in clinical practice as a quantitative measure to generate lists of potentially misutilized tests.
Methods: Testing frequencies from a database of clinical testing volumes for outpatients in Calgary, Canada, were obtained for the study period of 2016. For each chemistry, microbiology or hematology test, an arithmetic coefficient of variation (CV) was calculated from family physicians' ordering frequencies.
Results: The mean CV for all 358 tests considered was 219% (95% CI 206–231%) with a range of 52–729%. The highest variance was observed for human T-lymphotropic virus antibody testing and several tests for heavy metal levels (mercury, copper, zinc and chromium). Among the 100 most commonly run tests, high variance was found for several endocrinology tests including cortisol.
Conclusions: The utility of ranking clinical tests by ordering variance presents a practical approach to evaluate relative variation in physician practice strategy and to identify potential areas of misutilization.

1. Introduction

Effective stewardship is a critical priority for modern clinical laboratories as they face growing test volumes that are outpacing population growth amidst limited resources [1–6]. One exacerbating factor is the amount of unnecessary testing which has been estimated to account for 20–40% of all ordered tests [7]. Despite the acknowledged importance of optimizing test orders, there is little guidance on which tests to target for utilization management initiatives. Reviews commenting on inappropriately ordered tests have concluded that compliance with clinical practice guidelines is the most appropriate measure [1,8]. Initial testing has been found to be a larger contributor to overutilization compared to repeat testing, suggesting that more focus be put on ordering appropriate tests upon initial patient assessment [7].

While there may be contributing geographic and/or socioeconomic factors [9–12], inter-physician variance in test ordering practice can be considered an important marker of inappropriate use in clinical settings [13–16]. Thus, practice variance has the potential to provide a much needed objective marker of laboratory test misutilization. Unexplained variation in laboratory test utilization has often been noted [9–12,17], however no detailed analyses have been carried out thus far to identify potentially misutilized tests. Our previous work has shown that the total attributable cost of laboratory testing in Calgary, Canada, varies widely among primary care physicians with a coefficient of variation (CV) of 110% [18].

Here, we propose that high inter-physician variance in test utilization could be used to identify tests warranting consideration for utilization management initiatives. For each clinical test ordered by family physicians at our laboratory, we calculated arithmetic coefficient of variation (CV) as a measure of ordering variance. Family physicians were chosen as they account for more than half of all laboratory test orders [18] and to eliminate inter-specialty variation as a significant confounder. As Calgary Laboratory Services (CLS; recently consolidated to Alberta Public Laboratories) has been the sole diagnostic testing center for the City of Calgary in 2016 (catchment population: 1.4 million), the reported values encompass total test volumes performed for this population.

Abbreviations: CLS, Calgary Laboratory Services; LIS, Laboratory Information System

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2. Material and methods

CLS has maintained a database on its Laboratory Information System (LIS) containing information for over 200,000,000 tests ordered since 2008 by 3500+ physicians in the Calgary area. Test volumes within the study period of January to December 2016 by family physicians for community-based patients were extracted from the LIS as well as the number of patients who received any tests by each physician. Clinical laboratory tests included hematology, chemistry and microbiology tests. Inclusion criteria were: orders from family physicians seeing more than 10 patients in the study period, tests ordered 100 times or more, and ordered by 3 or more physicians. As this study was a quality improvement initiative, ethics approval was not required.

For each test, the ordering rate for each physician was calculated according to number of tests ordered and patients seen. To normalize the ordering rate distributions, the rates were log-transformed, $\ln(x) = X$, which were used to calculate the arithmetic means, $E(X)$, and variances, $Var(X)$. From there, the arithmetic coefficients of variation, CV, were calculated via a scale parameter, σ^2, as follows:

$$\sigma^2 = \ln\left(1 + \frac{Var(X)}{E(X)^2}\right) \quad (1)$$

$$CV = 100\% \times \sqrt{e^{\sigma^2} - 1} \quad (2)$$

95% confidence interval boundaries for CV's were calculated from:

$$Lower\ limit = \sqrt{e^{\frac{\sigma^2 df}{F_{\chi^2}(df,0.025)}} - 1} \quad (3)$$

$$Upper\ limit = \sqrt{e^{\frac{\sigma^2 df}{F_{\chi^2}(df,0.975)}} - 1} \quad (4)$$

where $F_{\chi^2}(df, x)$ is the cumulative distribution function of a central χ^2 distribution with degrees of freedom, $df = n - 1$.

3. Results

In the 1-y study period, 358 clinical tests in chemistry, hematology and microbiology were ordered at least 100 times by 1532 family physicians in Calgary. The mean CV for all tests was 219% (95% CI 206–231%) with a range of 52–729%. For the complete table showing all tests and their calculated CV's, see [19].

The twenty tests with the highest variance between physicians are shown in Table 1. The highest CV was found for human T-lymphotropic virus antibody testing (729%), which is highly ordered for transfusion donor blood. Four trace metal tests appeared on the list (mercury, 679%; copper, 592%; zinc, 534%; chromium, 488%) as well as ceruloplasmin (522%) which is used to investigate copper availability in the body. Five endocrine-related tests appeared as having high ordering variance: aldosterone (577%), morning cortisol (484%), dehydroepiandrosterone sulfate (DHEAS, 483%), thyroglobulin (553%), T3 reverse (510%), and total T4 (468%). Other high variance tests included phenytoin for anti-epileptic drug monitoring (594%), liver panel (559%), and post-vasectomy semen analysis (551%).

Variance was then considered among the 100 most commonly performed clinical tests, ranging from 4390 to 661,115 orders for homocysteine and complete blood count, respectively (Table 2). For these high volume tests, the mean CV was 182% (95% CI 163–201%) and many endocrine-related tests had high CV's: cortisol, 484%; DHEAS, 483%; progesterone, 352%; thyroid peroxidase antibody, 305%; estradiol, 291%; parathyroid hormone, 283%; and free T3, 264%. Two tests for vitamin deficiency monitoring also had high variance: homocysteine, 441%; and vitamin D, 385%.

A consideration of the most commonly performed tests showed the lowest CV's (Table 3). The ordering distributions for some of these tests between physicians are shown as box plots in Fig. 1. The tests with the highest CV's (red and orange) do not necessarily showed the largest IQRs in their dispersion, which highlights the utility of the calculated CV as a measure of utilization because it is also influenced by mean test ordering rate. The high volume tests (blue) had tighter IQRs.

4. Discussion

In this study, we identified clinical laboratory tests with the highest variance in ordering frequencies between family physicians in Calgary, Canada. The calculated CV's for each test present a practical approach to assess consistency in ordering practice among physicians and thereby, tests which represent potential targets for intervention can be recognized [20,21]. Such efforts to reduce the load of unnecessary testing will be beneficial not only for economic reasons, but also for overall quality of treatment and patient experience.

Clinical laboratory testing has been estimated to account for 3% of healthcare expenditures in the United States [1]. To have a significant impact on costs, tests subject to utilization management should be both commonly ordered and have significant variation among practitioners.

Table 1
Clinical laboratory tests with highest variance among family physicians (358 tests considered).

Rank	Test	Total tests ordered	% ordering physicians	Median tests per patient, *TPP* [a]	Arithmetic mean of ln(*TPP*)	% Arithmetic coefficient of variation, *CV* (95% CI)	
1	Human T-lymphotropic virus I and II Antibody	282	12.8	0.001508	0.00584	729	(512–1165)
2	Mercury	1154	7.8	0.001275	0.01479	679	(445–1248)
3	Phenytoin	1981	30.6	0.003082	0.02088	594	(478–771)
4	Copper	1008	9.5	0.001711	0.01603	592	(411–981)
5	Aldosterone	425	3.2	0.001439	0.01097	577	(327–1573)
6	Liver panel (BILT,ALP,ALT,GGT,LD,Lipase)	389	6.0	0.002362	0.01574	559	(363–1072)
7	Thyroglobulin	2516	32.0	0.002294	0.00918	553	(450–706)
8	Semen analysis post vasectomy	2327	10.4	0.001453	0.01620	551	(392–875)
9	Zinc	1290	11.2	0.001621	0.01791	534	(387–825)
10	Ceruloplasmin	1066	18.5	0.002262	0.00738	522	(404–721)
11	T3 reverse	741	6.1	0.001789	0.01860	510	(338–945)
12	Non-invasive prenatal testing	109	2.8	0.001484	0.02457	490	(281–1343)
13	Chromium	318	2.2	0.001536	0.02353	488	(264–1658)
14	Cortisol AM	5247	41.8	0.003528	0.01470	484	(408–590)
15	Dehydroepiandrosterone sulfate	9353	40.2	0.003735	0.02976	483	(407–591)
16	Rabies serology	403	11.7	0.00134	0.00423	481	(356–720)
17	Total T4	103	3.8	0.001067	0.00481	468	(289–1039)
18	Malaria	627	18.6	0.001799	0.00385	462	(364–625)
19	Reticulocyte count	4685	39.6	0.004242	0.01383	460	(389–561)
20	Drug screen urine comprehensive	2688	9.6	0.003046	0.08833	455	(330–705)

[a] Median number of tests ordered per patient among ordering physicians.

Table 2
Clinical laboratory tests with highest variance among family physicians (100 most commonly performed tests).

Rank	Test	Total tests ordered	% ordering physicians	Median tests per patient, *TPP* [a]	Arithmetic mean of ln (*TPP*)	% Arithmetic coefficient of variation, *CV* (95% CI)	
1	Cortisol AM	5247	41.8	0.003528	0.01470	484	(408–590)
2	Dehydroepiandrosterone Sulfate	9353	40.2	0.003735	0.02976	483	(407–591)
3	Reticulocyte count	4685	39.6	0.004242	0.01383	460	(389–561)
4	Homocysteine total	4390	18.1	0.002278	0.02742	441	(348–594)
5	Vitamin D 25 Hydroxy	9437	46.3	0.004219	0.02018	385	(334–455)
6	Progesterone	17,113	65.4	0.007951	0.02701	352	(313–400)
7	Potassium	9524	35.8	0.003509	0.02314	321	(277–381)
8	C-reactive protein	5471	16.8	0.003049	0.04072	311	(254–401)
9	Thyroid peroxidase antibody	18,559	68.9	0.009804	0.02645	305	(274–342)
10	Protein total	16,381	51.8	0.004451	0.03581	299	(265–342)
11	Hemoglobin electrophoresis	6472	55.6	0.004866	0.01353	293	(262–333)
12	Estradiol	26,410	76.0	0.014363	0.03515	291	(264–324)
13	Parathyroid hormone	4968	58.2	0.004785	0.01031	283	(254–319)
14	Glucose meter reading	4772	57.4	0.005289	0.01276	269	(242–303)
15	Syphilis	23,857	67.4	0.011593	0.02587	269	(244–300)
16	T3 Free	44,979	77.0	0.016245	0.05649	264	(241–292)
17	Wound culture	8098	70.6	0.007692	0.01777	260	(237–289)
18	Glucose gestational screen	11,080	43.2	0.004985	0.03182	257	(228–294)
19	Varicella zoster IgG	6425	63.2	0.005063	0.01163	257	(233–286)
20	Cholesterol total	10,094	46.3	0.003953	0.02080	256	(229–292)

[a] Median number of tests ordered per patient among ordering physicians.

Among the high volume tests, those with high variance included endocrine tests for adrenal, thyroid and reproductive organ function as well as tests for vitamin deficiency. The relatively high variance of 25-hydroxy vitamin D tests is of interest given the introduction of an intervention throughout Calgary in 2015 to reduce vitamin D deficiency population screening [22]. Several tests for heavy metal health showed the highest ordering practice variance, however they were ordered by no more than 20% of physicians.

The low variance associated with the most commonly run tests suggests that the utility of these routine tests is generally well understood and agreed upon by physicians. This is especially bolstered by clearly established practice guidelines from initiatives such as Choosing Wisely Canada [23]. However, there may be cases when low variance is reflective of widespread misutilization practice. For example, TSH testing has the lowest practice variance and, as the third most commonly run clinical test in Calgary, it is widely recognized for its overuse [22,24,25].

Family doctors were chosen as the group of study to demonstrate the utility of practice variance here because they account for over half of all test orders and their practice requires a broad range of testing services. This provides a wide overview of ordering practice that highlight tests that may be comparably over-ordered by some physicians, however there may be justifiable cases given the heterogeneity of medical conditions within a major municipality. Test orders from pediatricians were excluded from this analysis. There may be value in further segmenting the group of physicians being considered according to patient characteristics such as socioeconomic and age profiles, however this would undermine the diverse nature of family medicine.

For the 100 most commonly performed tests, ordering practice is expected to be more standardized and give better objective guidance for identifying targets of misutilization. Using the example of cortisol blood tests, the top 5 percentile of ordering physicians accounted for 62% of

Table 3
Practice variance among family physicians for the most commonly performed clinical laboratory tests.

Rank	Test	Total tests ordered	% ordering physicians	Median tests per patient, *TPP* [a]	Arithmetic mean of ln (*TPP*)	% Arithmetic coefficient of variation, *CV* (95% CI)		Rank, by *CV*
1	Complete blood count	661,115	99.7	0.6989	0.7326	58	(56–61)	357
2	Creatinine	572,773	99.0	0.6011	0.6479	70	(68–74)	351
3	Thyroid stimulating hormone	543,360	98.2	0.5305	0.5404	52	(50–54)	358
4	Electrolyte panel - Na, K, Cl, and CO2	469,090	97.2	0.4750	0.5488	85	(81–89)	340
5	Alanine aminotransferase	465,087	98.7	0.4328	0.4548	61	(59–64)	355
6	Hemoglobin A1c	433,985	96.7	0.4177	0.4347	59	(57–62)	356
7	Lipid profile (CHOL, TRIG, HDL, LDLCAL)	427,197	94.4	0.3914	0.4092	63	(60–66)	354
8	Ferritin	406,623	96.7	0.3375	0.3918	68	(65–71)	352
9	Urinalysis	405,288	98.0	0.3286	0.3908	71	(68–74)	350
10	Glucose fasting	220,113	87.7	0.0935	0.2083	115	(108–121)	303
11	Alkaline phosphatase	214,112	96.1	0.1048	0.2108	115	(109–122)	300
12	Gamma glutamyl transferase	206,557	95.7	0.1084	0.2097	111	(105–117)	309
13	Iron and TIBC	202,752	92.9	0.0961	0.1942	117	(111–124)	294
14	Vitamin B12	168,961	92.2	0.0812	0.1681	119	(113–126)	292
15	Glucose random	164,565	95.2	0.1013	0.1797	112	(106–118)	308
16	Urine culture	151,385	96.2	0.1601	0.2040	99	(94–104)	325
17	Albumin	151,192	94.2	0.0765	0.1799	137	(129–145)	256
18	Prothrombin time (INR)	141,729	90.1	0.1128	0.2580	204	(190–221)	154
19	Free T4	137,931	89.6	0.0564	0.1307	154	(145–164)	225
20	Calcium	134,120	92.5	0.0661	0.1602	136	(128–144)	259

[a] Median number of tests ordered per patient among ordering physicians.

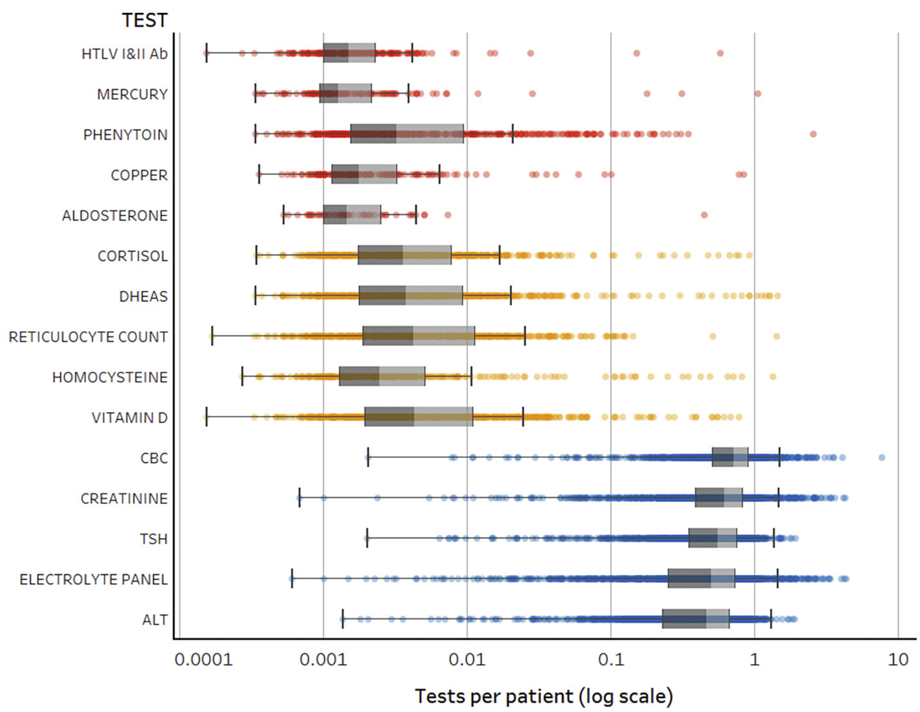

Fig. 1. Box plot distributions of test ordering rates among Calgary family physicians showing the 5 tests with highest CV (red), 5 tests with highest CV among 100 most ordered tests (orange), and 5 most ordered tests (blue). Boxes encompass the IQR, whiskers encompass median ± 1.5 IQR. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

test orders in 2016, amounting to a minimum estimated cost of $16,000 [26]. Interventions to bring awareness of these high variance tests may cause physicians to reconsider their ordering practice, especially in comparison among their peers [27], and better defined ordering guidelines.

There are a few limitations to this study. Primarily, the tests counted here only include those followed through by the patients. For a variety of reasons, there may be lab tests ordered by a family physician that are subsequently abandoned by patients. Also, anatomic pathology tests, bone marrow examinations and genetic tests were not considered as they are uncommonly requested by family physicians. Point-of-care testing was also not considered, however the geographic availability of these tests is likely to contribute to ordering variability.

Future work may include the segmentation of physicians by their patient characteristics, which may be reasonably achieved by geospatial mapping. Different areas of the city may present patient communities that are variable in sociodemographic factors including age, income and lifestyle (e.g. urban vs. suburban), which would influence clinical testing demand [28–30]. Furthermore, the mean abnormal result rate (MARR), a selectivity parameter reflecting the proportion of abnormal results for a test given its ordering volume, can be calculated as a distinct measure of a test's ordering appropriateness for comparison with its variance [31,32]. Finally, CV's may be followed in a longitudinal study to track patterns of practice variance change over several years.

5. Conclusions

In summary, we took advantage of inter-physician variance in clinical practice to provide guidance in identifying clinical laboratory tests warranting further investigation for utilization management. The objectivity of this information is defined by the type of testing and/or patient population being considered. As proof of concept, the analysis here is applied to the broad practice of family medicine where decreasing the amount of anomalous and unnecessary testing would not only have a direct economic benefit, but would also reduce additional clinic visits and improve overall patient experience. Although our results are specific to the range of tests offered by the testing facility in service of Calgary, this approach is generalizable and can be used in any jurisdiction or specialization to highlight medical services warranting utilization management.

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References

[1] A. Huck, K. Lewandrowski, Utilization management in the clinical laboratory: an introduction and overview of the literature, Clin. Chim. Acta 427 (2014) 111–117.
[2] P.M. Sluss, Reference laboratory utilization management, Clin. Chim. Acta 427 (2014) 167–172.
[3] M. Plebani, M. Zaninotto, D. Faggian, Utilization management: a European perspective, Clin. Chim. Acta 427 (2014) 137–141.
[4] C. Naugler, A perspective on laboratory utilization management from Canada, Clin. Chim. Acta 427 (2014) 142–144.
[5] J.Y. Kim, W.H. Dzik, A.S. Dighe, K.B. Lewandrowski, Utilization management in a large urban academic medical center: a 10-year experience, Am. J. Clin. Pathol. 135 (2011) 108–118.
[6] M.C. Alonso-Cerezo, J.S. Martin, M.A. Garcia Montes, V.M. de la Iglesia, Appropriate utilization of clinical laboratory tests, Clin. Chem. Lab. Med. 47 (2009) 1461–1465.
[7] M. Zhi, E.L. Ding, J. Theisen-Toupal, J. Whelan, R. Arnaout, The landscape of inappropriate laboratory testing: a 15-year meta-analysis, PLoS One 8 (2009) e78962.
[8] R.G. Hauser, B.H. Shirts, Do we now know what inappropriate laboratory utilization is? An expanded systematic review of laboratory clinical audits, Am. J. Clin. Pathol. 141 (2014) 774–783.
[9] W.P. Welch, M.E. Miller, H.G. Welch, et al., Geographic variation in expenditures for physicians' services in the United States, N. Engl. J. Med. 328 (1993) 621–627.
[10] M. Gornick, Medicare patients: geographic differences in hospital discharge rates and multiple stays, Soc. Secur. Bull. 40 (22–41) (1977) 11.
[11] T.L. Krupski, L. Kwan, A.A. Afifi, et al., Geographic and socioeconomic variation in the treatment of prostate cancer, J. Clin. Oncol. 23 (2005) 7881–7888.
[12] J. Busby, K. Schroeder, W. Woltersdorf, et al., Temporal growth and geographic variation in the use of laboratory tests by NHS general practices: using routine data to identify research priorities, Br. J. Gen. Pract. 63 (2013) e256–e266.
[13] J.E. Wennberg, Understanding geographic variations in health care delivery, N. Engl. J. Med. 340 (1999) 52–53.
[14] C.G. Macias, J.M. Mansbach, E.S. Fisher, et al., Variability in inpatient management of children hospitalized with bronchiolitis, Acad. Pediatr. 15 (2015) 69–76.
[15] R. Wahlstrom, E. Hummers-Pradier, C.S. Lundborg, et al., Variations in asthma treatment in five European countries–judgement analysis of case simulations, Fam. Pract. 19 (2002) 452–460.
[16] M.O. Meade, M.J. Jacka, D.J. Cook, et al., Survey of interventions for the prevention and treatment of acute respiratory distress syndrome, Crit. Care Med. 32 (2004)

946–954.
[17] C.M. Ashton, N.J. Petersen, J. Souchek, et al., Geographic variations in utilization rates in veterans affairs hospitals and clinics, N. Engl. J. Med. 340 (1999) 32–39.
[18] C. Naugler, R. Thomas, T.C. Turin, et al., Yearly clinical laboratory test expenditures for different medical specialties in a Major Canadian City, Am. J. Clin. Pathol. 144 (2015) 97–102.
[19] L.T. Nguyen, M. Guo, B. Hemmelgarn, et al., Ranking of Clinical Laboratory Tests According to Ordering Variance among Family Physicians in Calgary, Alberta, Canada, (2018) (Data in Brief (Submitted in Conjunction with this Article)).
[20] R.E. Thomas, M. Vaska, C. Naugler, et al., Interventions at the laboratory level to reduce laboratory test ordering by family physicians: systematic review, Clin. Biochem. 48 (2015) 1358–1365.
[21] R.E. Thomas, M. Vaska, C. Naugler, et al., Interventions to educate family physicians to change test ordering: systematic review of randomized controlled trials, Acad. Pathol. 3 (2016) (2374289516633476).
[22] C. Naugler, B. Hemmelgarn, H. Quan, et al., Implementation of an intervention to reduce population-based screening for vitamin D deficiency: a cross-sectional study, CMAJ Open 5 (2017) (E36-E9).
[23] Choosing Wisely Canada, www.choosingwiselycanada.org , Accessed date: 16 October 2017.
[24] A. Werhun, W. Hamilton, Thyroid function testing in primary care: overused and under-evidenced? A study examining which clinical features correspond to an abnormal thyroid function result, Fam. Pract. 32 (2015) 187–191.
[25] N. Chami, J.E. Simons, A. Sweetman, et al., Rates of inappropriate laboratory test utilization in Ontario, Clin. Biochem. 50 (15) (2017) 822–827.
[26] I. Ma, C.K. Lau, Z. Ramdas, et al., Estimated costs of 51 commonly ordered laboratory tests in Canada, Clin. Biochem. 65 (2019) 58–60.
[27] K. Ryskina, C. Jessica Dine, Y. Gitelman, et al., Effect of social comparison feedback on laboratory test ordering for hospitalized patients: a randomized controlled trial, J. Gen. Intern. Med. 33 (2018) 1639–1645.
[28] J. Barber, M. Guo, L.T. Nguyen, et al., Sociodemographic correlates of clinical laboratory test expenditures in a Major Canadian City, Am. J. Clin. Pathol. 148 (2017) 91–96.
[29] L. de Koning, D. Henne, P. Woods, et al., Sociodemographic correlates of 25-hydroxyvitamin D test utilization in Calgary, Alberta, BMC Health Serv. Res. 14 (2014) 339.
[30] A. Crouse, S.M. Sadrzadeh, L. de Koning, et al., Sociodemographic correlates of fecal immunotesting for colorectal cancer screening, Clin. Biochem. 48 (2015) 105–109.
[31] C.T. Naugler, M. Guo, Mean abnormal result rate: proof of concept of a new metric for benchmarking selectivity in laboratory test ordering, Am. J. Clin. Pathol. 145 (2016) 568–573.
[32] A.P. Brack, M. Guo, I. Ma, et al., Use of the mean abnormal result rate (MARR) to gauge changes in family Physicians' selectivity of laboratory test ordering, 2010–2015, Am. J. Clin. Pathol. 148 (2017) 436–440.