Laboratory testing in internal medicine: volume and patterns of use

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Laboratory testing has an indispensable role in modern medicine. Appropriateness of its use might have an impact on resource utilization, further diagnostics, and treatment decisions.

Summary
The aim of this retrospective observational study was to assess the volume of laboratory testing, to describe the distribution of orders and parameters, to investigate patterns of use, and, identifying potential targets for optimization. Laboratory tests performed in all inpatients of the department of internal medicine of the Stadtspital Zürich Triemli in the years 2017–2020 were studied. A total of 558,760 parameters distributed over 89'086 orders from 23,467 patients were performed. A median of 3 orders and 17 parameters were requested per patient; 4 out of 120 parameters accounted for almost half of the testing volume. Within the first orders, 12 parameters were tested in >30% of orders and accounted for 77% of the testing volume. When focusing on the first two orders, three distinct patterns were identified that grouped parameters according to high, intermediate, or low repetition rates in the second order. The interval duration between the first two orders was associated with distinct parameter profiles: intervals <6 hours were associated with higher prevalence of cardiovascular biomarkers compared to longer intervals.

Introduction
Laboratory testing plays an indispensable role in clinical diagnosis, monitoring of response to treatment, and prognostication of a large number of clinical conditions. However, excessive and inappropriate blood tests can lead to uncertainty in further downstream investigations and interventional procedures by the doctors, and to psychological distress and hospital-acquired anemia in patients (2). This study aimed to assess the use of inpatient laboratory testing in a large department of internal medicine in Switzerland. In particular, we aimed to i) describe the distribution of orders and parameters, ii) investigate patterns of use, and iii) identify potential strategic targets for resource optimization.

Methods
The study was conducted at the Stadtspital Zürich Triemli, a 500-bed tertiary hospital in Zurich. Data about all laboratory orders related to patients admitted to the Department of Internal Medicine (including intensive care unit) between January 1, 2017, and December 31, 2020, were retrospectively collected from the electronic laboratory database. Cumulative data on demographics, length of stay, and mortality were collected from the clinical key data system. The database consists of anonymized, depersonalized records on all performed orders including unique case and order identification numbers, date and time of analysis, and tested parameters. Analyses performed from the first or second blood draw during the inpatient stay are classified as first or second order, respectively. For the purpose of this study, we excluded hematological, microbiological, and genetic/molecular analyses, as well all analyses performed in media other than serum/plasma.

Results

Study population
From January 1, 2017, to December 31,2020, a total of 23,467 patients were admitted to the Department of Internal Medicine and underwent at least one laboratory analysis. The median age was 72 years (interquartile range, IQR 57–82 years) and 12,453 patients (53%) were males. According to the hospital operating figures, 20% of patients were admitted electively as opposed to the majority of patients admitted from the emergency department. The mean length of hospital stay was 6.8 days, the in-hospital mortality was 5% and the readmission rate was 3%. A total of 89,086 laboratory orders consisting of 558,760 tested parameters were performed during the study period with a median of 3 orders (IQR 2–5) and 17 parameters (IQR 11–28) per hospital stay. Of note, a steady decrease in the total number of requested parameters over the study period was observed (2017: 20 (13–32); 2018: 17 (11–28); 2019: 16 (10–26); 2020: 14 (9–23), $p < 0.001$).

Tested parameters in the overall cohort
Among all orders (n = 8,086), 120 different parameters were tested. Creatinine (tested in 73% of all orders, n = 64,917), potassium (69%, n = 61,254), C-reactive protein (66%, n = 59,150), sodium (66%, n = 58,428), and alanine aminotransferase (31%, n = 27,260) were tested most frequently (in >30% of orders) and, cumulatively, accounted for a substantial volume of all laboratory tests performed (n = 271,009, 48.5% of the total of 558,760) (Figure 1).

Tested parameters in the first order of hospital stay
When focusing only on the very first order of each hospital stay (n = 23,467), a total of 234,185 parameters was tested. Twelve parameters were tested very frequently (in >30% of first orders) and accounted for 77% of the volume of tests (Figure 2). Four of them (creatinine, sodium, potassium, C-reactive protein) were tested in >90% of first orders. Figure 2 shows the proportion of the most frequently tested parameters among the first order.

“Of the 23,467 first orders, 18 082 (77%) were followed by a second order.”

First and second orders

Of the 23,467 first orders, 18,082 (77%) were followed by a second order. The median number of parameters tested in the first and second orders were 10 (IQR 8–13) and 4 (IQR 2–5), respectively. The median interval between the first and second order was 17.5 hours (IQR 3.2–42.9). More than one of three orders were repeated within 6 hours from the first order, one of four between 6 and 24 hours and the remaining more than 24 hours after the first order (Figure 4, main panel).

To explain the large proportion of second orders requested within 6 hours, we analyzed which parameters were repeatedly tested in the first and second orders. We compared the tested parameters in orders repeated within 6 hours (n = 6,584) and compared with those performed >6 hours apart (n = 11,498). We found a striking difference in the tested parameters: in the short interval group, the most frequently repeated parameters were high-sensitivity troponin T (n = 5,209, 79%), creatine kinase (n = 4,375, 66%), creatine kinase MB (n = 2,798, 42%), creatinine (n = 611, 9%), and potassium (n = 520, 8%), while in the longer interval group, the most frequently repeated parameters were creatinine (n = 8,127, 71%), potassium (n = 7,760, 67%), sodium (n = 7,684, 67%), C-reactive protein (n = 7,191, 63%), and alanine aminotransferase (n = 1,649, 14%).

We further tested the percentage of repetition of the most commonly tested parameters (n = 45) in the second laboratory orders. As depicted in Figure 5, three different patterns of repetition – related to the clinical information of the tested parameter – could be found. The first pattern (“mandatory”, Figure 5, Box A) includes parameters that very often require serial measurements for correct interpretation. As an example, high-sensitivity troponin T is measured in both the first and second order in 85% of cases. The second pattern includes those parameters in which a recheck is largely dependent on the clinical context (“contextual”, Figure 5, Box B) and displays a rate of recheck of approximately 40–60%. As an example, C-reactive protein displays a recheck rate of 43%. The third pattern includes those parameters in which a recheck is usually not indicated (“obsolete”, Figure 5, Box C). These parameters show a recheck rate below 20%. For example, thyroid-stimulating hormone (TSH) belongs to this pattern and displays a percentage of repetition of 1%.

Discussion

This retrospective single-center study describes the distribution of orders, testing parameters and patterns of use of inpatient laboratory testing in a large internal medicine department. By analyzing all consecutive laboratory orders over a period of four years, we describe the total volume of testing and identify the most commonly performed tests and their patterns of use within the same order and across repetitive orders.

First, we showed that the volume of testing is substantial. Over the four years of the study period, more than half a million parameters have been tested, which translates to a median of 17 parameters per patient, distributed over a median of 3 laboratory orders. As expected, our data displayed a positive skewness, with few patients receiving 10 or more orders during the course of hospitalization. Of note, however, the number of orders in our study was substantially lower than the number reported in a contemporary study from the Netherlands (5).

We further observed a 30% decrease in the median number of tested parameters over the four years of study duration, which translated to a significant 37% decrease in the laboratory costs per patients (data not shown). Finally, when comparing our data with another contemporary Swiss cohort, we found a markedly lower median number of tested parameters per patient, despite comparable baseline characteristics and a higher disease severity (case mix) in our hospital (6).

Second, we showed that among the 120 different parameters that were tested at least once during the study period, about two-thirds of them were requested only very rarely (<1% of orders) and accounted for a negligible testing volume. Conversely, 5 parameters (i.e., creatinine, potassium, sodium, C-reactive protein, and alanine aminotransferase) were requested very frequently (>30% of orders) and accounted for nearly half of the total testing volume. Along this line, when focusing exclusively on the initial order of each patient, only 12 parameters were requested very frequently (>30% of orders), which, however, accounted for more than three-quarters of the testing volume. In particular, four parameters (i.e., creatinine, potassium, sodium, C-reactive protein) were tested in >90% of orders.

Third, in 3 of 4 patients two or more orders were placed, in most cases probably to monitor and follow-up selected parameters measured at the first order. This interpretation is highlighted by the fact that the second orders included significantly fewer parameters than the first ones (4 vs. 10). Moreover, among the second orders most of the parameters were already tested at the first order. In other words, only few parameters were tested for the first time in the second order.

Surprisingly, we found a rather short median interval between the first two orders of less than 18 hours, with more than one-third of the patients receiving their second order within 6 hours. This rather large proportion of patients receiving two orders of blood tests only a few hours apart is strongly related to repeated measurement of cardiovascular biomarkers in patients with suspected acute coronary syndrome, which account for a relevant proportion of emergency admissions to our hospital.

Fourth, we analyzed the proportion of repetition of each parameter in the second order and observed three different patterns. The “mandatory” pattern includes those parameters that need to be repeated to achieve a correct interpretation. For example, high-sensitivity troponin needs to be repeated after 1–3 hours when an acute coronary syndrome is suspected unless the initial value is very low. The “contextual”

Figure 1

Parameter	№	CRP	NA	K	MG	CA	PO4	OSM	BUN	CREA	ALT	AST	AP	GGT	BILT	ALB	LIP	GLU	LDH	TSH	FT4	FT3	CK	CKMB	TNT	BNP	ALC
	22382	22408	21589	1046	3360	1554	1479	6656	22723	15640	11650	12538	4298	11648	4411	3233	8826	3636	15364	1127	1050	8888	4994	7326	1728	1510
CRP	22382	100%	98%	94%	4%	15%	7%	7%	29%	99%	69%	51%	56%	19%	51%	19%	14%	39%	16%	68%	5%	5%	38%	21%	31%	8%	7%
NA	22408	97%	100%	95%	4%	15%	6%	7%	29%	99%	68%	51%	55%	19%	51%	19%	14%	39%	16%	67%	5%	5%	38%	21%	31%	7%	7%
K	21589	97%	99%	100%	4%	15%	6%	6%	29%	99%	69%	52%	55%	19%	51%	19%	14%	39%	16%	67%	5%	5%	39%	21%	31%	7%	7%
MG	1046	94%	78%	77%	100%	39%	74%	14%	50%	94%	73%	62%	60%	24%	60%	45%	15%	37%	25%	67%	5%	5%	55%	33%	42%	10%	12%
CA	3360	98%	99%	94%	12%	100%	27%	11%	47%	99%	81%	65%	69%	31%	67%	89%	20%	48%	35%	78%	7%	7%	40%	18%	24%	10%	9%
PO4	1554	95%	87%	84%	50%	58%	100%	14%	58%	97%	78%	65%	65%	29%	65%	63%	18%	39%	32%	71%	6%	5%	47%	26%	33%	11%	12%
OSM	1479	99%	99%	93%	10%	25%	15%	100%	44%	99%	78%	59%	65%	24%	63%	33%	19%	47%	21%	76%	6%	5%	34%	16%	24%	7%	11%
BUN	6656	98%	97%	93%	6%	24%	13%	10%	100%	99%	76%	66%	62%	28%	66%	31%	17%	45%	26%	78%	7%	6%	45%	28%	36%	13%	6%
CREA	22723	97%	98%	94%	4%	15%	7%	6%	29%	100%	68%	51%	55%	19%	51%	19%	14%	39%	16%	67%	5%	5%	38%	21%	31%	7%	6%
ALT	15640	99%	98%	95%	5%	17%	8%	7%	32%	99%	100%	62%	71%	26%	66%	23%	20%	42%	21%	73%	5%	5%	41%	23%	32%	8%	8%
AST	11650	98%	97%	97%	6%	19%	9%	7%	38%	99%	83%	100%	74%	31%	73%	26%	23%	44%	27%	73%	5%	5%	43%	26%	32%	9%	8%
AP	12538	99%	98%	96%	5%	19%	8%	8%	33%	99%	89%	69%	100%	29%	74%	25%	24%	46%	23%	74%	6%	5%	42%	25%	32%	9%	8%
GGT	4298	99%	98%	95%	6%	25%	10%	8%	44%	99%	94%	84%	86%	100%	85%	34%	30%	45%	32%	77%	6%	5%	38%	24%	30%	10%	10%
BILT	11648	99%	98%	94%	5%	19%	9%	8%	38%	99%	89%	73%	79%	31%	100%	27%	27%	44%	26%	73%	5%	5%	42%	26%	33%	9%	8%
ALB	4411	98%	98%	94%	11%	68%	22%	11%	47%	99%	82%	66%	70%	33%	71%	100%	22%	47%	35%	76%	7%	7%	36%	16%	22%	10%	10%
LIP	3233	99%	99%	96%	5%	21%	8%	9%	36%	99%	94%	83%	92%	40%	96%	30%	100%	53%	31%	61%	4%	4%	48%	33%	30%	7%	9%
GLU	8826	99%	98%	95%	4%	18%	7%	8%	34%	99%	74%	56%	66%	22%	58%	23%	20%	100%	17%	73%	5%	5%	45%	29%	34%	10%	8%
LDH	3636	98%	97%	96%	7%	33%	14%	9%	48%	99%	90%	86%	78%	37%	85%	43%	28%	40%	100%	74%	6%	6%	42%	22%	30%	11%	7%
TSH	15364	98%	98%	94%	5%	17%	7%	7%	34%	99%	74%	55%	60%	22%	55%	22%	13%	42%	18%	100%	7%	7%	43%	24%	37%	9%	7%
FT4	1127	98%	98%	94%	5%	22%	8%	8%	38%	98%	76%	57%	62%	22%	57%	27%	12%	40%	20%	98%	100%	92%	44%	26%	38%	12%	5%
FT3	1050	98%	98%	94%	5%	21%	8%	8%	39%	99%	77%	57%	62%	21%	56%	28%	12%	40%	20%	99%	99%	100%	44%	27%	38%	13%	5%
CK	8888	96%	95%	94%	6%	15%	8%	6%	34%	97%	73%	56%	59%	19%	55%	18%	17%	45%	17%	74%	6%	5%	100%	54%	78%	12%	7%
CKMB	4994	95%	93%	91%	7%	12%	8%	5%	37%	96%	73%	60%	62%	21%	60%	14%	21%	51%	16%	74%	6%	6%	96%	100%	91%	17%	5%
TNT	7326	95%	94%	91%	6%	11%	7%	5%	33%	96%	69%	51%	55%	18%	52%	13%	13%	41%	15%	77%	6%	5%	92%	62%	100%	15%	5%
BNP	1728	98%	97%	93%	6%	19%	10%	6%	50%	99%	75%	60%	63%	20%	60%	29%	12%	51%	22%	83%	8%	8%	64%	50%	64%	100%	3%
ALC	1510	96%	96%	94%	8%	20%	12%	11%	28%	98%	80%	64%	65%	30%	65%	29%	20%	46%	17%	70%	4%	3%	42%	16%	22%	3%	100%

Figure 2

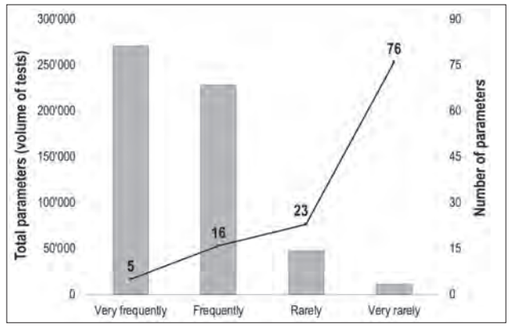

Figure 3

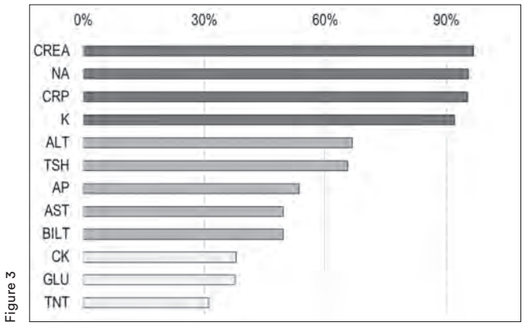

Figure 4

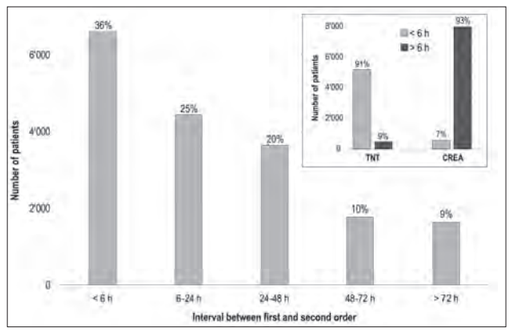

Figure 1: Associations of selected parameters among first order tests at a large internal medicine department in a Swiss tertiary hospital.

Figure 2: Frequency and volume of tested parameters. Dots and line depict the number of parameters in each category of testing frequency: very frequently, frequently, rarely, very rarely.

Figure 3: Frequency of laboratory parameters ordered.

Figure 4: Interval between first and second order and its association with selected parameters.

Figure 5: Percentage of repeated tests in the second laboratory order. The main diagram shows the percentage of repetition of the most commonly performed tests, the size of the circles represents the number of performed tests.

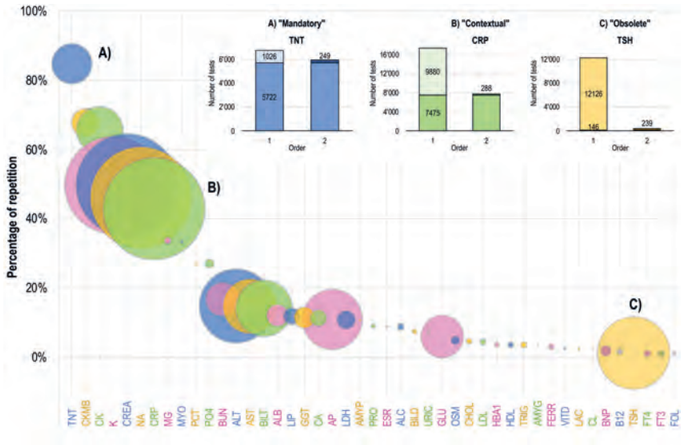

Figure 5

pattern displays a recheck rate of 40–60% and includes those parameters in which the recheck is largely dependent on the clinical context. For example, C-reactive protein is mostly rechecked when the initial value is elevated and the further clinical course suggests treatment failure (11, 12). The "obsolete" pattern includes parameters that should not be routinely rechecked and displays a recheck rate below 20% (mostly <10%).

The grouping of parameters in these three distinct patterns is relevant for the development of strategies aimed at reducing unnecessary testing. For the "mandatory" group, it is unlikely that the rate of repetition can significantly be reduced by staff education. However, in light of the current recommendations, one might argue whether the (serial) measurement of creatine kinase and creatine kinase MB is still necessary for patients with a suspected acute coronary syndrome (13, 14). The limitation to one single, very sensitive biomarker would not reduce the number of order but the volume of tested parameters.

In conclusion, we analyzed the use of inpatient laboratory testing in one of the largest departments of internal medicine in Switzerland. Our data describe the distribution of orders and identify distinct patterns of use. These results are of interest for medical educators, quality managers in health care and policymakers. Further efforts should be undertaken to implement strategies to optimize utilization of laboratory tests in clinical practice. ●

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