Value of electrocardiogram and chest X-ray examinations in preoperative management

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Aims: An electrocardiogram (ECG) and chest X-ray (CXR) are widely used in the preoperative period for patients undergoing non-cardiac surgery (NCS). We aimed to assess whether preoperative ECG and CXR had any impact on changes in preoperative management for an unselected population undergoing non-elective NCS.

Methods: We retrospectively reviewed records of hospitalized patients undergoing an internal preoperative examination in 2015-2021. The primary endpoint was a change in preoperative management that caused postponement or complete cancelation of a surgery (PCCS), due to an abnormal ECG or CXR.

Results: We enrolled 2362 patients. 72% had an abnormal ECG and 33% had an abnormal CXR. PCCS due to an abnormal ECG or CXR occurred in 4 (0.17%) and 5 (0.21%) patients, respectively. In all cases, the change in preoperative management was due to a supraventricular tachyarrhythmia (SVT) on the ECG or pneumonia on the CXR. Patients with PCCS due to SVT had a rapid heart rate (HR) (mean 141 bpm vs. 79 bpm in others). An HR cut-off value <125 bpm had a 100% negative predictive value (NPV) for PCCS. Patients with PCCS due to pneumonia had higher C-reactive protein levels (CRP) (median 189 mg/l vs. 7 mg/l in others). A CRP cut-off value <62 mg/l had 100% NPV for PCCS. There was an increased 90-day postoperative all-cause mortality risk in patients with HR above 100 bpm (RR=2.08), increasing even more with higher HRs, and abnormal CXR findings compared to normal CXR (RR=2.49).

Conclusions: Both ECG and CXR had very limited value in the preoperative management of hospitalized patients undergoing non-elective NCS. We recommend HR (>100 bpm) and CRP (>61 mg/l) as indicators for ECG and CXR testing, rather than age, as an addition to patient history and clinical findings. HR above 124 bpm should distinguish the patients with higher probability of changes in preoperative management. We also recommend using an abnormal CXR (if available) and a heart rate exceeding 100 bpm to identify patients at a higher relative risk of postoperative mortality.

Keywords: Arrhythmias, C-Reactive Protein, Electrocardiography, Pneumonia, Retrospective Studies, X-rays

Význam elektrokardiogramu a rentgenu hrudníku v předoperačním managementu

Cíle: Elektrokardiogram (EKG) a rentgen hrudníku (CXR) jsou běžně používány v předoperačním období u pacientů podstupujících nekardiální operace (NCS). Cílem této studie bylo zhodnotit, zda mají předoperační EKG a CXR vliv na změny v předoperačním managementu u neselektované populace podstupující neplánované NCS.

Metody: Retrospektivně jsme analyzovali záznamy hospitalizovaných pacientů, kteří podstoupili interní předoperační vyšetření v letech 2015–2021. Primárním cílovým ukazatelem byla změna předoperačního managementu, která vedla k odložení nebo úplnému zrušení operace (PCCS) z důvodu abnormálního EKG nebo CXR.

Výsledky: Do studie bylo zařazeno 2362 pacientů. Abnormální EKG mělo 72 % a abnormální CXR 33 % pacientů. PCCS z důvodu abnormálního EKG nebo CXR se vyskytlo u 4 (0,17 %) a 5 (0,21 %) pacientů. Ve všech případech byla změna předoperačního

managementu způsobena supraventrikulární tachyarytmií (SVT) na EKG nebo pneumonií na CXR. Pacienti s PCCS kvůli SVT měli rychlý srdeční rytmus (HR) (průměrně 141 tepů za minutu oproti 79 u ostatních). Hodnota HR pod 125 tepů/min měla 100% negativní prediktivní hodnotu (NPV) pro PCCS. Pacienti s PCCS kvůli pneumonii měli vyšší hodnoty C-reaktivního proteinu (CRP) (medián 189 mg/l oproti 7 mg/l u ostatních). Hodnota CRP pod 62 mg/l měla 100% NPV pro PCCS. Riziko 90denní pooperační úmrtnosti bylo zvýšené u pacientů s HR nad 100 tepů/min (RR=2,08), přičemž riziko dále rostlo s vyšším HR, a u pacientů s abnormálním CXR ve srovnání s normálním CXR (RR=2,49).

Závěry: EKG i CXR měly velmi omezenou hodnotu v předoperačním managementu hospitalizovaných pacientů podstupujících neplánované NCS. Doporučujeme použít HR (> 100 tepů/min) a CRP (> 61 mg/l) jako indikátory pro testování EKG a CXR, spíše než věk, jako doplněk k anamnéze a klinickým nálezům. HR nad 124 tepů/min by měl odlišit pacienty s vyšší pravděpodobností změn v předoperačním managementu. Také doporučujeme využít abnormální CXR (pokud je dostupný) a HR přesahující 100 tepů/min k identifikaci pacientů s vyšším relativním rizikem pooperační úmrtnosti.

Klíčová slova: arytmie, c-reaktivní protein, elektrokardiografie, pneumonie, retrospektivní studie, rentgenové snímky.

Introduction

An electrocardiogram (ECG) and a chest X-ray (CXR) are widely used in the preoperative period for patients undergoing non-cardiac surgery (NCS), even before a low-risk surgery. However, guideline recommendations are to limit these tests in low-risk cases (1-2).

A previous multivariate analysis showed that patients over 64 years old with a history of hypertension were at greater risk of major ECG changes (3), and that finding was supported by other studies (4). However, an analysis of over 150 000 patients revealed that a preoperative ECG (despite being abnormal) provided only limited clinical information, beyond the patient's demographic and clinical history, for predicting in-hospital deaths and perioperative myocardial infarctions (5). In low-risk patients that underwent low-risk surgery, a preoperative ECG did not predict early treatment termination and triggered very few surgery cancelations; thus, it had very little effect on preoperative management (6). In a study of 991 patients over 40 years of age that underwent an elective NCS, an abnormal ECG rarely interfered with preoperative management (7). On the other hand, a prospective study from 2002 suggested that an ECG should be conducted in patients over 40 years of age or those with cardiac or respiratory symptoms prior to an elective NCS, even though an abnormal ECG led to preoperative changes in only 0.5% of the patients (8). Older studies on patients prior to an elective NCS reported a low to high prevalence of ECG abnormalities, but they had little influence on preoperative management (9-10). No randomized controlled trial has shown that a preoperative ECG could reduce postoperative complications or mortality. Furthermore, one study showed that a disturbing percentage of ECGs were not even reviewed prior to an NCS (11).

A preoperative CXR is unnecessary in many patients undergoing an elective surgery (12), but it greatly increases the costs (13-14). In a small study (in an elective setting), a high percentage of older patients (over 70 years) had abnormal findings on a preoperative CXR (15); however, changes in preoperative management due to these findings were not studied. Moreover, surgical or anesthetic procedures are rarely modified due to an abnormal CXR in general surgery for patients without cancer (16-17). Consequently, age, and a few other cut-off values, have been proposed to limit the routine use of preoperative CXR (18-20). A study from 1988 showed that there were no complications directly associated with the lack of preoperative CXR (21). Another study showed that perioperative complications did not increase as a result of no preoperative testing (in a given population of ambulatory patients undergoing surgery) (22). In a multi-center study, the usefulness of preoperative CXR increased with age and The American Society of Anesthesiologists (ASA) physical status classification system (23).

While in foreign countries the performance of ECG and CXR leads to an increase in the cost of surgery, in the Czech Republic, the cost of ECG or CXR does not significantly increase the overall surgical costs, but on the other hand might lead to an increased staff workload, thus wasting valuable personal resources.

However, those studies were performed either on somewhat selected groups of patients or prior to an elective NCS. The present study investigated the value of preoperative ECG and CXR and their impact on changes in preoperative management in an unselected population undergoing non-elective NCS.

Methods

Study design and patients

This study was designed as a retrospective, single-center analysis, based on hospital records of patients that underwent internal preoperative examinations before a non-elective NCS. There were no exclusion criteria. A computerized search identified all consecutive patients that underwent an internal examination required by any specialty, between November 2015 and September 2021. The total number of reviewed internal examinations was 4074. Of these, 2362 were preoperative internal examinations. All 2362 preoperative internal examinations were included in the analysis to provide unselected patient data.

All enrolled patients were hospitalized and scheduled for non-elective NCS. The surgeries included postponable, semi-acute, acute, and urgent. The fields of surgery included abdominal surgery, traumatology, urology, neurosurgery, gynecology, vascular surgery, proctosurgery, and otorhinolaryngology.

For each enrolled patient, we recorded 53 parameters. These parameters included age, sex, disease history, surgical field, height, weight, body-mass index (BMI), smoking, basic laboratory parameters, blood

pressure, detailed descriptions of the ECG and CXR, changes in pre-operative management, complications after surgery, and mortality.

Study goals

The primary goal of this analysis was to determine whether an ECG or CXR, acquired prior to non-elective NCS in hospitalized patients, had any impact on changes in preoperative management. We defined a change in a preoperative management as a postponed or completely canceled surgery (PCCS). We also recorded any relevant changes in preoperative medications, such as adjustments in beta-blocker doses or anti-arrhythmic therapy. Sometimes, additional tests were initiated, based on an abnormal ECG or CXR, which turned out to be unnece-ssary and did not provide any additional information. Therefore, those tests did not actually change the preoperative management. In those cases, we did not record a change in preoperative management; on the contrary, we recorded these as pointless time delays.

The secondary goal was to identify potential predictors of a change in preoperative management, due to ECG or CXR findings. We aimed to suggest some cut-off values of the identified predictors, which could be used to reduce the number of unnecessary procedures.

Study oversight

The study was conducted in accordance with Good Clinical Practice guidelines, and it was approved by the local Ethics Committee. Given the retrospective study design, patients did not provide informed consent before study entry.

All the authors involved had access to all patient data and the results of statistical analyses. All the authors agreed to vouch for the accuracy and completeness of the analyzed data.

Statistical analysis

Standard descriptive statistics were applied in the analysis. Continuous variables are expressed as the mean ±SD or the median and interquartile range. Categorical variables are expressed as absolute and relative frequencies. Differences between patients with and without PCCS were analyzed with the Mann-Whitney test, for continuous vari-ables, and Fisher's exact test, for categorical variables.

Parameters were selected for their abilities to predict PCCS; this was evaluated with a receiver operating characteristic (ROC) analysis and described with the area under the curve (AUC), its confidence interval (CI), and statistical significance (p-value <0.05). The optimal cut-off values were determined by maximization of the Youden index. The analysis was performed in SPSS 28. 0. 1.1 (IBM Corporation, Armonk, NY, USA, 2021).

Results

We enrolled a total of 2362 patients scheduled for NCS that underwent an internal preoperative examination between September 2015 and November 2021. All patients were included in the primary analysis. Their mean age was 63.4 years, and 48% were women. Among these patients, 56.4% had a history of arterial hypertension, 22.8% had a history of diabetes, and 16.5% had a history of chronic coronary syn-

drome. The mean heart rate was 79 beats per minute (bpm); the median serum C-reactive protein (CRP) level was 8 mg/l. The clinical and other characteristics of the patients are provided in Table 1.

Prior to surgery, only 6 patients did not undergo ECG testing, and 86 patients did not undergo CXR testing. Among these patients, 72% had an abnormal ECG and 33% had an abnormal finding on a CXR. Characteristics of the physiological ECGs and abnormal CXRs used in this study are described in Tables 2 and 3.

A PCCS due to a pathological ECG or CXR finding occurred in 4 (0.17%) and 5 (0.21%) patients, respectively, in the entire group. Supraventricular tachyarrhythmia (SVT) was the only reason for a change in preoperative management due to the ECG findings. Pneumonia was the only reason for a PCCS due to CXR findings.

Tab. 1. *Patient clinical and other characteristics*

Parameter	Category	Value
Age, y		63 (±15)
Sex	Men	1.227 (51.9)
	Women	1.135 (48.1)
Hypertension	No	1.030 (43.6)
	Yes	1.332 (56.4)
Dyslipidemia	No	1.758 (74.4)
	Yes	604 (25.6)
Atherosclerosis	No	2.091 (88.5)
	Yes	271 (11.5)
Chronic coronary syndrome	No	1.972 (83.5)
	Yes	390 (16.5)
Chronic heart failure	No	2.299 (97.3)
	Yes	63 (2.7)
Chronic kidney disease	No	2.222 (94.1)
	Yes	140 (5.9)
Ischemic or hemorrha-gic stroke	No	2.157 (91.3)
	Yes	205 (8.7)
Atrial fibrillation	No	2.169 (91.8)
	Yes	193 (8.2)
Diabetes mellitus	No	1.824 (77.2)
	Yes	538 (22.8)
Pulmonary disease	No	2.053 (86.9)
	COPD	133 (5.6)
	AB	100 (4.2)
	ACOS	14 (0.6)
	Other	62 (2.6)
Oncological disease, malignancy	No	2.026 (85.8)
	Yes	336 (14.2)
BMI, kg/m²		28 (± 6)
Smoking	Non-smoker	1.381 (58.5)
	Smoker	702 (29.7)
	Ex-smoker	279 (11.8)
Potassium, mmol/l		4.24 (±0.48)
CRP, mg/l		8 (3–43)
Systolic blood pressure, mmHg		139 (±21)
Diastolic blood pressure, mmHg		80 (±12)
Heart rate, beats/min		79 (±16)

Values are the mean (± standard deviation), number (%), or median (intraquar-tile range), as indicat-ed. COPD – chronic obstructive pulmonary disease; AB – bronchial asthma; ACOS – asthma-COPD overlap syndrome; CRP – C-reacti-ve protein

Tab. 2. *Characteristics of a physiological ECG; any ECG findings other than those listed were considered abnormal*

Parameter	Normal Values
Rhythm	sinus rhythm, including respiratory arrhythmia
Rate	below 100 beats/min
PQ interval	120-200 ms
QRS interval	below 120 ms
QT interval	below 450 ms
ST segment	no changes in ST segment
T wave	negative T wave in leads III, aVR, V1

Tab. 3. *Characteristics of an abnormal chest X-ray*

Characteristic	Diagnosis
Cardiothoracic index above 0.5	aortic dilatation
pulmonary congestion	fluidothorax
mediastinal dilatation	pneumonia
atelectasis	tracheal deviation or stenosis
pleuritis	adhesions or post-inflammatory changes
emphysema	tumor or metastases
rib fractures	pneumothorax

Tab. 4. *Reasons for unnecessary testing or surgery delay, with no change in pre-operative management*

Aortic dilatation on CXR, TTE with only mild dilatation
Poorly described CXR image
Suspected pneumothorax, CT negative
Pulmonary congestion on CXR, TTE normal or insignificant
Pneumonia on CXR, but surgery urgent
CTI above 0.5, TTE with restrictive filling pattern
Pneumonia on CXR, pulmonary consult negative
Ischemic changes on ECG, biomarkers negative
Ischemic changes on ECG, TTE negative
Abnormal ECG, HCM on bed-side TTE, no risk or other change
Atrial fibrillation on ECG, TTE with mid-range ejection fraction
Abnormal ECG, TTE with reduced ejection fraction

CXR – chest X-ray; TTE – transthoracic echocardiography; CT – computed tomography; CTI – car-diothoracic index; ECG – electrocardiogram; HCM – hypertrophic cardiomyopathy

A preoperative adjustment in beta-blocker or anti-arrhythmic therapy was recommended in 8 (0.34%) patients. An unnecessary test or delay in surgery, due to an abnormal ECG and CXR finding, occurred in 35 (1.48%) and 16 (0.68%) patients, respectively. Reasons for unnecessary tests and delays are listed in Table 4.

The relationship between selected patient characteristics and PCCS due to ECG and CXR findings is shown in Tables 5 and 6. All patients with a PCCS due to an SVT on the ECG had a significantly higher heart rate (HR) than those without an SVT (mean HR: 141 vs. 79 bpm, p=0.001). All patients with an SVT had an HR above 124 bpm. These patients were also significantly older than the others (mean 77 vs. 63 years, p=0.048), and all were over 71 years old. Further analysis showed that ages ≥72 years and heart rates ≥125 bpm were statistically significant predictors of a change in preoperative management, due to an abnormal ECG (Table 7). There

Tab. 5. *Relationship between selected patient characteristics and surgery post-ponement or cancelation, due to electrocardiogram findings*

Parameter	Category	No Delay N = 2.358	PCCS N = 4	P
Age, y		63 (±15)	77 (±6)	**0.048**
Hypertension	No	1.029 (43.6)	1 (25.0)	0.637
	Yes	1.329 (56.4)	3 (75.0)	
Chronic coronary syndrome	No	1.971 (83.6)	1 (25.0)	**0.016**
	Yes	387 (16.4)	3 (75.0)	
Chronic heart failure	No	2.296 (97.4)	3 (75.0)	0.103
	Yes	62 (2.6)	1 (25.0)	
Ischemic or hemorrhagic stroke	No	2.154 (91.3)	3 (75.0)	0.305
	Yes	204 (8.7)	1 (25.0)	
Atrial fibrillation	No	2.167 (91.9)	2 (50.0)	**0.036**
	Yes	191 (8.1)	2 (50.0)	
Diabetes	No	1.820 (77.2)	4 (100.0)	0.580
	Yes	538 (22.8)	0 (0.0)	
Pulmonary disease	No	2.051 (87.0)	2 (50.0)	0.050
	COPD	132 (5.6)	1 (25.0)	
	AB	100 (4.2)	0 (0.0)	
	ACOS	14 (0.6)	0 (0.0)	
	Other	61 (2.6)	1 (25.0)	
BMI		27.8 (±5.6)	29.6 (±7.9)	0.402
Smoking	Non-smoker	1.379 (58.5)	2 (50.0)	0.062
	Smoker	702 (29.8)	0 (0.0)	
	Ex-smoker	277 (11.7)	2 (50.0)	
Potassium, mmol/l		4.24 (±0.48)	4.13 (±0.22)	0.556
CRP, mg/l		8 (3–42)	68 (5–157)	0.292
Systolic blood pressure, mmHg		139 (±21)	128 (±18)	0.299
Diastolic blood pressure, mmHg		80 (±12)	71 (±10)	0.144
Heart rate, beats/min		79 (±16)	141 (±15)	**0.001**

Values are the mean (±standard deviation), number (%), or median (intraquartile range), as indicat-ed. PCCS – postponement or canceling of surgery; SD – standard deviation; COPD – chronic pul-monary obstructive disease; AB – bronchial asthma; ACOS – asthma-COPD overlap syndrome; BMI – body-mass index; CRP – C-reactive protein; IQR – interquartile range

Tab. 6. *Relationship between selected patient characteristics and postponement or canceling of surgery due to chest X-ray findings*

Parameter	Category	No Delay N = 2,357	PCCS N = 5	P
Age		63 (±15)	81 (±7)	**0.007**
Hypertension	No	1,028 (43.6%)	2 (40.0%)	0.999
	Yes	1,329 (56.4%)	3 (60.0%)	
Chronic coronary syndrome	No	1,969 (83.5%)	3 (60.0%)	0.193
	Yes	388 (16.5%)	2 (40.0%)	
Chronic heart failure	No	2,294 (97.3%)	5 (100.0%)	0.999
	Yes	63 (2.7%)	0 (0.0%)	
Ischemic or hemorrhagic stroke	No	2,152 (91.3%)	5 (100.0%)	0.999
	Yes	205 (8.7%)	0 (0.0%)	
Atrial fibrillation	No	2,165 (91.9%)	4 (80.0%)	0.347
	Yes	192 (8.1%)	1 (20.0%)	
Diabetes	No	1,820 (77.2%)	4 (80.0%)	0.999
	Yes	537 (22.8%)	1 (20.0%)	
Pulmonary disease	No	2,048 (86.9%)	5 (100.0%)	0.999
	COPD	133 (5.6%)	0 (0.0%)	
	AB	100 (4.2%)	0 (0.0%)	
	ACOS	14 (0.6%)	0 (0.0%)	
	Other	62 (2.6%)	0 (0.0%)	
BMI, kg/m²		27.8 (±5.6)	28.4 (±5.4)	0.576
Smoking	Non-smoker	1,376 (58.4%)	5 (100.0%)	0.243
	Smoker	702 (29.8%)	0 (0.0%)	
	Ex-smoker	279 (11.8%)	0 (0.0%)	
Potassium, mmol/l		4.24 (±0.48)	3.78 (±0.57)	0.050
CRP, mg/l		7 (3–42)	189 (108–231)	**0.001**
Systolic blood pressure, mmHg		139 (±21)	136 (±19)	0.911
Diastolic blood pressure, mmHg		80 (±12)	71 (±11)	0.067
Heart rate, beats/min		79 (±16)	71 (±10)	0.196

Values are the mean (±standard deviation), number (%), or median (intraquartile range), as indicat-ed. PCCS – postponement or canceling of surgery; COPD – chronic pulmonary obstructive disease; AB – bronchial asthma; ACOS – asthma-COPD overlap syndrome; BMI – body-mass index; CRP – C-reactive protein

Tab. 7. *Age and heart rate predict change in preoperative management due to electrocardio-gram*

Predictor	AUC (95% CI)	P	Cut-off	Sensitivity	Specificity	PPV	NPV	Overall accuracy
Age, y	0.786 (0.696–0.876)	**0.048**	≥ 72	100.0%	67.1%	0.5%	100.0%	67.2%
HR, bpm	0.995 (0.991–1.000)	**0.001**	≥ 125	100.0%	98.8%	12.1%	100.0%	98.8%

AUC – area under the receiver operating characteristic curve; CI – confidence interval; NPV – neg-ative predictive value; PPV – positive predictive value; HR – heart rate; bpm – beats per minute

Tab. 8. *Age and CRP as predictors of change in preoperative management due to chest X-ray*

Predictor	AUC (95% CI)	P	Cut-off	Sensitivity	Specificity	PPV	NPV	Overall accuracy
Age, y	0.850 (0.744–0.955)	**0.007**	≥ 70	100.0%	61.5%	0.5%	100.0%	61.6%
CRP, mg/l	0.913 (0.855–0.971)	**0.001**	≥ 62	100.0%	80.6%	1.2%	100.0%	80.6%

AUC – area under the receiver operating characteristic curve; CI – confidence interval; NPV – neg-ative predictive value; PPV – positive predictive value; CRP – C-reactive protein

was also a significant association between chronic coronary syndrome, atrial fibrillation and the risk of PCCS, although on a lower level of statistical significance (p=0.016 and p=0.036 respectively).

All patients with a PCCS due to pneumonia detected on a CXR had a significantly higher CRP level than those without pneumonia (median CRPs: 189 vs. 7 mg/l, p=0.001). All patients with pneumonia had CRP levels above 61 mg/l. These patients were also older than the others (mean 81 vs. 63 years, p=0.007), and all were over 69 years old. Furthermore, we found that ages ≥70 years and CRP levels ≥62 mg/l were statistically significant predictors of a change in preoperative management, due to an abnormal CXR (Table 8).

There was a significant association between 90-day postoperative all-cause mortality and preoperative heart rate (HR). When using heart rate of 70-79 bpm as a reference point, there was a significantly elevated risk of 90-day postoperative all-cause mortality in patients with HR above 100 bpm (2.08, p=0.005), relative risk further increasing with the higher heart rates, for the detailed distribution of relative risks in the heart rate spectrum see the Table 9 and the Diagram 1.

Additionally, there was significantly increased risk of 90-day postoperative all-cause mortality in patients with abnormal CXR (RR=2.49, p=0.001) compared to patients with normal CXR findings (see Table 10).

Tab. 9. *Relative risk of 90-day postoperative all-cause mortality by preoperative heart rate*

		No. of death (no. of pa-tients)	RR (95% CI)	P
Heart rate [bpm]	< 50	1 (14)	1.20 (0.18–8.16)	0.189
	50–59	5 (135)	0.62 (0.25–1.56)	0.312
	60–69	17 (430)	0.66 (0.38–1.17)	0.155
	70–79	37 (623)	Reference	
	80–89	26 (430)	1.02 (0.63–1.66)	0.942
	90–99	26 (310)	1.41 (0.87–2.29)	0.161
	100–109	20 (162)	2.08 (1.24–3.48)	**0.005**
	110–119	8 (63)	2.14 (1.04–4.39)	**0.038**
	120–129	7 (26)	4.53 (2.24–9.19)	**<0.001**
	≥ 130	5 (19)	4.43 (1.96–10.01)	**<0.001**

RR – relative risk; CI – confidence interval

Tab. 10. *Relative risk of 90-day postoperative all-cause mortality by chest X-ray*

		RR (95% CI)	P
X-ray of the lungs	Normal	Reference	
	Abnormal	2.49 (1.83–3.39)	**<0.001**

RR – relative risk; CI – confidence interval

Discussion

This study showed that only a very limited number of patients that underwent a non-elective NCS (approximately 2 out of 1000) required changes in preoperative management due to abnormal ECG or CXR findings. This finding suggested that, for every 500 preoperative procedures, only 1 patient required a significant alteration in preoperative management. Therefore, in most patients, there is little benefit in performing ECG and CXR testing routinely prior to a non-elective NCS.

Similar results were reported in other studies on low-risk patients or patients that underwent an elective NCS (6-10, 16-17). Our results largely confirmed and expanded those results to an unselected patient population.

It could be argued that a preoperative ECG or CXR should be performed to reduce perioperative complications and perioperative and postoperative mortality. However, no randomized controlled trial has shown that preoperative ECGs could reduce postoperative complications or mortality. Conversely, some studies have suggested that a lack of preoperative CXR was not associated with perioperative complications (21-22).

In our study, the absence of changes in preoperative management was largely predictable, with very high sensitivity and a high NPV, based on age, heart rate, and CRP. The cut-off values we identified could provide reasonable tools for limiting unnecessary preoperative testing.

In a previous study on patients with hip fractures, only 0.6% of preoperative CXR findings resulted in a PPCS (24). Moreover, those findings were consistent with the preoperative clinical evaluations. Our data were consistent with the data from that study, but we studied a larger, unselected patient population. We found that 4 out of the 5 patients that had a PCCS due to CXR findings also had abnormal findings on pulmonary auscultation and objective or subjective difficulties during a preoperative clinical evaluation (the one remaining patient had inconclusive auscultatory findings).

In some patients, a preoperative CXR may impact the postoperative management (25). Moreover, some authors have suggested that the inability to compare pre- and postoperative CXRs may result in different postoperative management. In the present study, we could not address this issue, due to the lack of this type of data.

Some previous studies have suggested cut-off values for limiting the number of preoperative ECG and CXR tests. Cut-off values were reported for comorbidities, ASA class, respiratory and cardiac signs and symptoms, but mainly age. The proposed cut-off for age-based ECG and CXR testing ranged between 40 to 65 years (3-4, 7-8, 18-20). However, the results of our study showed that age alone was not a good predictor of PCCS, because it had relatively low specificity in predicting both the ECG and CXR findings (see Tables 7 and 8).

As seen in the results section, relative risk of 90-day postoperative all-cause mortality was significantly higher in patients with heart rate above 100 bpm (when using 70-79 bpm as a baseline reference point). The heart rate over 100 bmp is easily distinguishable during clinical examination. This suggests that we now have simply acquirable risk factor of postoperative mortality even before we proceed to ECG testing. The role that the heart rate should play in preoperative management is discussed below.

Based on our data, we suggest that an HR cut-off value of >100 bpm should trigger preoperative ECG testing. This suggestion is

Diagram 1. *Relative risk of 90-day postoperative all-cause mortality by preoperative heart rate*
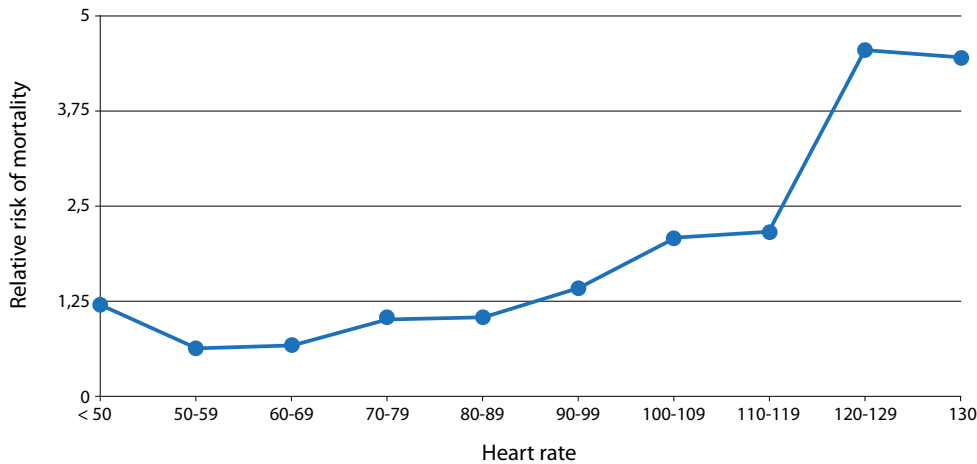
based on the risk probability for PCCS and 90 day postoperative mortality data. Any patient with HR above 100 bpm is at increased risk of postoperative mortality as seen in the results. It would be most convenient to distinguish between patients with increased relative risk of mortality and patients with increased risk of PCCS, which is significantly higher in patients with HR above 124 bpm. The difference between normal rhythm and tachycardia (i.e., an HR >124 bpm) is easily distinguishable during routine clinical physical examinations. Alternatively, HR can be detected during automatic blood pressure measurements or with pulse oximetry. 294/2362 (12.4%) patients had HRs over 100 bpm; thus, with cut-off values even as low as 100 bpm, 87.6% of unnecessary ECG tests could be prevented - saving valuable resources in today's medicine - healthcare professionals. HR over 100 bpm should give the information of increased risk of 90-day postoperative all-cause mortality, but not necessarily predict the change in the course of action in preoperative management. However closer monitoring of patients with increased risk of mortality should be emphasized.

Based on the results, ECG should also be performed in patients with previously known chronic coronary syndrome and atrial fibrillation, which also increase the risk of PCCS.

The results show, that patients with abnormal CXR have an increased risk of 90-day postoperative all-cause mortality (RR=2.49) compared to patients with normal CXR findings. These results should not be very surprising, as older patients and patients with comorbidities tend to have higher probability of abnormal CXR changes. Question remains, whether CXR holds additional information to patient history and clinical findings. Another question is, how to use this information. We now know, that abnormal CXR increases risk of postoperative mortality, but only handful of CXR are actually used to change preoperative management.

Despite the fact that abnormal CXR predicts increased risk of postoperative mortality, we suggest that a CRP cut-off value of >61 mg/l should trigger preoperative CXR testing. Due to the very low CRP levels we observed in the entire group of patients that underwent a non-elective NCS, this cut-off value could potentially avoid a vast number of unnecessary CXR procedures. Only 431/2362 (18.25%) patients had CRP levels above 61 mg/l; thus, this CRP cut-off value might prevent 81.75% of unnecessary CXR tests. Indeed, nearly half of the patients (1169/2362 [49.49%]) had CRP levels even lower than 10 mg/l, which suggested that a CXR was highly redundant. As a conclusion to this discrepancy, we think that preoperative CXR (if available) should be used to predict the need for better postoperative monitoring (keeping in mind that actual additional value to patient history and clinical finding is not known), but should not be performed in order to potentially change preoperative management, unless there is another indication such as breathlessness, pathological auscultation, low blood oxygen saturation or CRP >61 mg/l.

We identified no cut-off value for low heart rate, as there was not enough patients with low enough heart rate to make a difference in the preoperative management - no patient had any severe kind of bradycardia. Moreover, the empirical data display very low probability of bradycardia in patients before non-elective preoperative management. Rare cases of preoperative bradycardia must be dealt with on the individual basis.

This study and its results have no interest in diminishing the value of clinical evaluation prior to non-cardiac surgery, in fact the opposite. We believe that HR and CRP should be used as cut-off values for triggering additional preoperative testing in those cases, where clinical examination is normal or inconclusive, thus avoiding unnecessary tests in otherwise healthy patients. Clinical evaluation still remains a cornerstone of any preoperative management and all patients with positive clinical findings (such as breathlessness, pathological auscultation, low blood oxygen saturation) should have CXR before non-cardiac surgery.

The main limitations of our study were its single-center focus and retrospective design. The results may not be generalizable to other hospitals. On the other hand, the large number of enrolled patients in our study and the enrollment of consecutive patients within the given time period suggested that the results are statistically solid. Moreover, the simple design of our study provided the potential for easy reproduction on a larger scale.

Conclusion

We concluded that, based on our findings, both ECG and CXR are of a very limited value in the routine preoperative management of hospitalized patients undergoing a non-elective NCS. We recommend using the HR and CRP cut-off values we identified for triggering ECG and CXR testing, as an addition to positive clinical findings. These cut-off values should be more effective than the previously identified age cut-offs, which have lower specificity and, overall, lower accuracy. The ECG should be limited to patients with HR >100 bpm during clinical examination (to bare in mind that relative risk of mortality increases above 100 bpm, but the risk of PCCS increases only with HR above 124 bpm), or to patients with previously known chronic coronary syndrome and atrial fibrillation. CXR should be limited to patients with CRP levels >61 mg/l and patients with positive clinical findings (breathlessness, positive auscultation, low blood oxygen saturation). If performed, CXR could be used to predict the need for better postoperative monitoring (keeping in mind that actual additional value to patient history and clinical finding is not known).

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