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Age-corrected intraoperative tachycardia correlates with postoperative electrocardiographic alterations

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Abstract

Purpose. The intrinsic heart rate (IHR) has been calculated by an age-dependent formula; $118.1 - 0.57 \times$ Age (years). The aim of this study was to examine whether intraoperative tachycardia of different criteria correlates with the incidence of alterations of postoperative electrocardiograms (ECG).

Methods. One hundred and twenty-two patients who underwent elective laparotomy in general surgery were studied. Tachycardia was defined as a heart rate of either 100, 110, 120, or 130 beats per minute or more, and heart rates of 1.1, 1.2, 1.3, or 1.4 times or more of the IHR. Postoperative ECG alterations were defined as positive when (1) one or more of the first letters of Minnesota Code I, IV, and V were newly added, or (2) Q-waves extended to an adjacent lead, or (3) new ST-segment depression or elevation of 0.1mV or more was observed at 80ms beyond the ST-junction. Correlations between intraoperative tachycardia of different criteria and alterations in 12-h postoperative ECG were investigated.

Results. The incidence of postoperative ECG alterations was significantly greater when the intraoperative heart rate exceeded 1.2 IHR ($143 - 0.7 \times$ Age) for 30min and 1.3 IHR ($151 - 0.7 \times$ Age) for 5min ($P = 0.04$ and $P = 0.003$, respectively).

Conclusion. Age-corrected intraoperative tachycardia showed a good correlation with the incidence of postoperative ECG alterations.

Key words Intrinsic heart rate (IHR) · Age-corrected tachycardia · Intraoperative tachycardia · Postoperative ECG alteration

Introduction

Tachycardia during anesthesia is unfavorable for cardiac muscles from the viewpoint of the oxygen supply and demand relationship, and it may cause alterations on an intraoperative and/or postoperative electrocardiogram (ECG).

Jose and Collison [1] administered a mixture of propranolol ($0.2\,mg \cdot kg^{-1}$) and atropine sulfate ($0.04\,mg \cdot kg^{-1}$) to 432 healthy subjects, with ages ranging from 16 to 70 years, to produce pharmacological denervation of the autonomic nervous system. They measured the heart rates 5min later and determined the intrinsic heart rate (IHR). A major determinant of IHR was age: IHR $= 118.1 - 0.57 \times$ Age ($r = 0.644$, $P < 0.001$).

In the present study, the following heart rates were defined as tachycardia for patients who underwent elective laparotomy: 100bpm [2–4], 110bpm [5,6], 120bpm, and 130bpm [7] or more, and heart rates of 1.1 times, 1.2 times, 1.3 times, and 1.4 times or more greater than IHR. The purpose of the present study was to examine which of these eight criteria of intraoperative tachycardia show better correlation with alterations on a 12-h postoperative ECG. It was also an attempt to assess whether ECG alterations correlated with muscle–brain (MB) fraction of creatine kinase (MBCK) in the serum collected 12h after an operation.

Methods

The study was performed with the approval of the Institutional Ethics Committee of our hospital on 131 patients who were classified as cardiovascular functional classes 1 and 2 according to the Canadian Cardiovascular Society (CCVS) [8], and physical status 1, 2, and 3 according to the American Society of Anesthesiologists (ASA), and who all underwent elective laparotomy in general surgery within a period of 1 year. Information was given to the patients in writing and orally, and written consent was obtained from each patient.

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Atropine sulfate (0.4–0.5 mg) and hydroxyzine (25–50 mg) were given intramuscularly to all patients as premedication 30 min before the induction of anesthesia. Induction of anesthesia and endotracheal intubation were performed with thiamylal (4–5 $mg \cdot kg^{-1}$) and suxamethonium (0.8–1.0 $mg \cdot kg^{-1}$), and anesthesia was maintained with nitrous oxide and oxygen (4:2 $1 \cdot min^{-1}$) and 0.5%–3.0% enflurane. During the operation, 0.1 mg fentanyl was administered intravenously to patients with intraoperative tachycardia with hypertension; 10 mg oral nifedipine or 0.1 mg intravenous fentanyl was administered to patients with intraoperative hypertension when necessary. Pancuronium bromide was used as a muscle relaxant.

A 12-lead electrocardiograph (Kartizer-5500; NEC San-ei, Tokyo, Japan) provided with a bandpass filter of frequency response 0.05–100 Hz [9], and incorporating an interpreter in accordance with the Minnesota Code, was employed, and ECGs were taken before and 12 h after the operation. Alterations on the ECG were defined as positive when (1) one or more of the first letters of the Minnesota Code I, IV, and V (code on the Q-wave, ST-segment, and T-wave, respectively) were newly added in the postoperative ECG [10], (2) Q-waves were extended to new adjacent leads [2], or (3) there was preexisting ST-segment deviation, and a new ST-segment depression or elevation of 0.1 mV or more was observed at 80 ms beyond the ST-junction on the postoperative ECG.

A venous blood sample was collected 12 h after the operation. Measurement of the serum MBCK was performed at a commercial laboratory (Bio-Medical Laboratory, Matsumoto, Japan) using a chemiluminescent immunoassay (CLIA).

Heart rate during anesthesia was determined every 2.5 min by averaging the preceding eight heartbeats on the ECG monitor. The wave rate of a pulse–oximeter and the pulse rate of the radial artery were used when the ECG monitor was affected by other electrical devices. Tachycardia during anesthesia was determined by each tachycardia threshold (100 bpm, 110 bpm, 120 bpm, 130 bpm, 1.1 IHR, 1.2 IHR, 1.3 IHR, and 1.4 IHR), and the total intraoperative duration was considered to be the total tachycardia time (TTT). Since there were eight different definitions of tachycardia, eight different values of TTT were obtained for each patient.

Either the χ^2-test or Fisher's exact test was applied (for dichotomous variables) to evaluate the association of two factors. To examine the difference in the means in the two groups, Student's t-test was performed when there was an equality of variance; Welch's test was performed when equality of variance was not obtained. P-values less than 0.05 were considered as statistically significant. Continuous data were expressed as mean ± SD.

Results

The investigation was performed on 131 possible patients. Among these, two patients declined to participate, and seven exhibited atrial fibrillation. Hence, 122 patients finally participated in the investigation. Among the 122 patients, 45 were hypertensive, 6 were suspected of old myocardial infarction according to the preoperative ECG (only one had an evident history), 19 suffered from anemia (hematocrit <30) accompanying advanced digestive tract cancer, 7 had complications from cerebrovascular stroke, 6 were diabetic, and 3 were asthmatic. Four of the 7 patients who were classified as CCVS class 2 were receiving nifedipine and one received nitrate. Of the 45 hypertensive patients, 41 were receiving a depressor (calcium channel blocker and/or angiotensin converting enzyme inhibitor). None of the patients were receiving drugs that have an effect on heart rate (i.e., propranolol, verapamil, or reserpine). Two or three hours before the operation, 23 patients were treated with nitroglycerin patch or isosorbide dinitrate (ISDN) tape to lower blood pressure or coronary artery dilation.

Electrocardiographic alterations

Of the 122 patients, alterations between pre- and postoperative ECGs were noted in 20 patients (16%). Table 1 shows the altered leads of ECG and postoperative serum MBCK. None of the cases showed additional ST-segment depression or elevation of 0.1 mV or more. Case 19 showed a postoperative symmetrically inverted T-wave on ECG, which returned to a normal upright T-wave 2 weeks later. Because this patient was suspected of having ischemia, he was treated with ISDN tape for 29 days and discharged 34 days after the operation. Table 2 summarizes the backgrounds of the patients and their ECG alteration rates. CCVS classification and preoperative nitrate treatment was correlated with the alteration rate of ECG ($P < 0.05$). The mean age of patients who had no ECG alterations was 63 ± 12 years, while the mean age of those who showed ECG alterations was 73 ± 11 years ($P < 0.01$). The anesthetic durations of these two groups were 232 ± 98 min and 226 ± 112 min, and this difference was not significant. The pre- and postoperative values of the electrolytes of the two groups are shown in Table 3. The values of postoperative Na and Cl in the group with ECG alterations were lower than in those in the group showing no ECG alterations.

MB fraction of creatine kinase (MBCK)

Serum MBCK had a log–normal probability distribution. Between the group of 102 patients who showed no

Table 1. Altered leads of ECG and 12-h postoperative serum MBCK (ng·ml^{-1})

	Patient No.	Leads	MBCK
New I	10	III	2.4
	19	III, aV_F	15.6
	21	V_2	8.3
	38	V_1	2.3
	43	aV_F	5.0
	60	III, aV_F	4.4
	87	V_2	8.2
	120	V_1, V_2	10.0
	129	III, aV_F	2.0
New IV	24	I, aV_F	5.3
New V	20	V_6	4.3
	35	V_3	8.5
	62	V_4–V_6	1.8
	101	V_4–V_6	2.4
	112	aV_L	2.0
	125	V_5–V_6	6.0
Q-wave extending	5	$V_1 \rightarrow V_1$–V_2	7.2
	6	$V_1 \rightarrow V_1$–V_2	10.9
	49	V_1–$V_2 \rightarrow V_1$–V_3	6.0
	126	V_1–$V_4 \rightarrow V_1$–V_5	6.3

New I, IV, and V, the first letters of the Minnesota Code I, IV, or V were newly added in the postoperative ECG
No. 126, old myocardial infarction (segment 6)
No. 19, giant negative T-wave on postoperative ECG
In noncardiac surgery, the reference value of MBCK for postoperative myocardial infarction is twice as high as the so-called medical normal range (~7.5 ng·ml^{-1}) [2,10]

Table 2. Background of patients and postoperative ECG alteration rate

		N	*n*	*n*/*N* (%)
Overall		122	20	16
Sex:	male	66	10	15
	female	56	10	18
CCVS	I	115	16	14 ⎤*
	II	7	4	57 ⎦
ASA	I	26	1	4
	II	76	14	18
	III	20	5	25
Site:	upper	46	8	17
	lower	35	7	20
	L–GB–P	30	3	10
	Misc.	11	2	—
HT	−	77	10	13
	+	45	10	22
Anemia	−	103	15	15
	+	19	5	26
ECGabn	−	102	15	15
	+	20	5	25
Nitrate	−	99	12	12 ⎤*
	+	23	8	35 ⎦

N, total numbers in category; n, numbers with ECG alteration; CCVS, classification according to Canadian Cardiovascular Society; ASA, physical status according to American Society of Anesthesiologists; Upper, upper digestive tract; Lower, lower digestive tract; L–GB–P, liver, gall bladder, and pancreas; HT, hypertension; ECGabn, preoperative ECG with the first letters of Minnesota Code I, IV, or V; Nitrate, preoperative nitrate administration
* $P < 0.05$

Table 3. Pre- and postoperative electrolyte analysis and ECG alteration

	Alter[a] (−) (n_1 = 102)	Alter (+) (n_2 = 20)	Test *P*-value
Pre			
Na (mEq·l^{-1})	141.5 ± 2.8	140.4 ± 4.4	ns
K (mEq·l^{-1})	4.2 ± 0.3	4.3 ± 0.6	ns
Cl (mEq·l^{-1})	106.0 ± 3.4	104.7 ± 4.6	ns
Ca (mg·dl^{-1})	9.2 ± 0.5	9.2 ± 0.7	ns
Post			
Na (mEq·l^{-1})	137.8 ± 3.7	135.6 ± 4.2	$P = 0.02$*
K (mEq·l^{-1})	4.4 ± 0.5	4.6 ± 0.6	ns
Cl (mEq·l^{-1})	102.0 ± 3.6	100.0 ± 3.2	$P = 0.02$*
Ca (mg·dl^{-1})[b]	8.2 ± 0.5	8.6 ± 1.1	ns

[a] Alter, postoperative ECG alteration
[b] $n_1 = 71$, $n_2 = 13$
* $P < 0.05$

alterations on postoperative ECG and the group of 20 patients who exhibited alterations, there was no difference in log-MBCK value measured 12 h after the operation (1.57 ± 0.68 *vs* 1.60 ± 0.64; $P = 0.88$).

Beats-per-minute units and IHR units

When heart rate was compared in actual bpm units, the patients with ECG alterations had higher heart rates 12 h after the operation (Table 4). When heart rate was compared in IHR units taking the age of the patients into account, patients showing ECG alterations had higher heart rates than those showing no ECG alterations, not only 12 h after operation ($P < 0.001$), but also at the completion of anesthesia ($P < 0.01$).

Total tachycardia time (TTT)

The correlation coefficients between TTT based on the eight tachycardia definitions and MBCK value were calculated. None of these eight TTTs correlated with the MBCK value. The correlation coefficients between TTT and ECG alterations were also studied. In cases where the tachycardia threshold was defined as 1.2 times or 1.3 times IHR, there was a statistically significant correlation between TTT and ECG alterations ($r = 0.182$, $P < 0.05$; $r = 0.242$, $P < 0.01$, respectively).

TTT was then divided into two time categories: time less than *k* min (*k* is a set time value) and time greater than *k* min (Table 5). In the group of patients who showed a heart rate of 1.2 IHR (143 − 0.7 × Age) or more for more than 30 min during anesthesia, the postoperative ECG exhibited more alterations than the group showing a heart rate of 1.2 IHR or more for less than 30 min (26% *vs* 11%, $P = 0.04$; Table 6). In the group of patients showing heart rate of 1.3 IHR

Table 4. Comparison of heart rates between patients showing no ECG alterations and patients with ECG alterations

	Alter (−) (n_1 = 102)	Alter (+) (n_2 = 20)	Test *P*-value
Actual beats per min units			
Ward	74.4 ± 9.5	73.6 ± 11.8	ns
EnterOR	80.5 ± 17.1	78.4 ± 19.6	ns
EndAne	81.9 ± 14.3	85.5 ± 12.0	ns
PostOpe	76.0 ± 12.8	85.8 ± 14.4	$P = 0.003$**
IHR units			
Ward	0.91 ± 0.14	0.97 ± 0.18	ns
EnterOR	0.98 ± 0.23	1.04 ± 0.29	ns
EndAne	1.00 ± 0.20	1.13 ± 0.19	$P = 0.009$**
PostOpe	0.93 ± 0.18	1.13 ± 0.21	$P = 0.00002$**

Alter, postoperative ECG alteration; Ward, resting in ward; EnterOR, entering an operating room; EndAne, at the completion of anesthesia; PostOpe, 12 h postoperation
** $P < 0.01$

2 × 2 contingency table for Table 5

	TTT < *k*	*k* ≦ TTT	
Alter (−)	A	B	102
Alter (+)	C	D	20
	A + C	B + D	122

Table 5. Time *k* (min) and number of patients in four subsets

	k-min	A	B	C	D	Test
100 bpm	5	42	60	10	10	ns
	10	48	54	11	9	ns
	15	59	43	13	7	ns
	30	73	29	17	3	ns
	45	82	20	17	3	ns
	60	86	16	18	2	ns
	75	92	10	19	1	ns
110 bpm	5	74	28	13	7	ns
	10	85	17	16	4	ns
	15	92	10	19	1	ns
120 bpm	5	96	6	19	1	ns
130 bpm	5	101	1	19	1	ns
1.1 IHR	30	40	62	5	15	ns
	60	57	45	7	13	ns
	90	66	36	11	9	ns
	120	76	26	13	7	ns
1.2 IHR	15	54	48	7	13	ns
	30	67	35	8	12	*
	45	80	22	11	9	*
	60	85	17	12	8	*
1.3 IHR	5	68	34	6	14	**
	10	77	25	9	11	**
1.4 IHR	5	89	13	11	9	**

* $P < 0.05$; ** $P < 0.01$

(151 − 0.7 × Age) or more for more than 5 min during anesthesia, the postoperative ECG showed more alterations than the group showing the same heart rate for less than 5 min (29% *vs* 8%, $P = 0.003$; Table 7).

Table 6. ECG alterations in patients with 1.2 IHR for over 30 min

	TTT < 30	30 ≦ TTT	
Alter (−)	67	35	102
Alter (+)	8	12	20
	75	47	122
	(8/75 = 11%	12/47 = 26%)	

χ^2-test: $P = 0.04$

Table 7. ECG alterations in patients with 1.3 IHR for over 5 min

	TTT < 5	5 ≦ TTT	
Alter (−)	68	34	102
Alter (+)	6	14	20
	74	48	122
	(6/74 = 8%	14/48 = 29%)	

χ^2-test: $P = 0.003$

Discussion

According to Breslow et al. [11], new T-wave abnormalities were found in about 19% of postoperative ECGs, but these abnormalities were not specific to cardiac muscle ischemia, and did not correlate with age, sex, or ASA classification. The report of Irish et al. [12] was similar to that of Breslow et al., although their postoperative ECG alteration rate was 22%. In contrast, Parsloe et al. [13] reported that 53 out of 200 patients (25%) showed postoperative ST/T alterations, three of them suffered from myocardial infarction, and preoperative ECG abnormality, ischemic heart disease, and a high rank of ASA classification were correlated with the postoperative ST/T alterations. In the present study, the result was similar to that in the report by Parsloe et al. except that the postoperative alteration rate was as low as 16%.

As reported by Parsloe et al. [14], anemia (low hematocrit) sometimes led to ischemic changes on ECG. The correlation between anemia and ECG alterations was investigated in present study (see Table 2), and showed that 15 out of 103 (15%) and 5 out of 19 (26%) were found to be statistically insignificant ($P = 0.20$).

ECG alterations were found in those patients who were treated with a nitrate patch or tape before the operation (see Table 2), but nitrate administration was not the reason for the ECG alterations. As nitrate was usually used to treat patients who were diagnosed by ECG as having cardiovascular abnormalities in blood pressure or heart rate, ECG alterations might result from those abnormalities.

Charlson et al. [15] reported that intraoperative increases or decreases of 20 mmHg or more in mean arterial pressure (MAP) resulted in a significant increase in complications, that changes in pulse rate of 20 bpm or more were not independent predictors of complications, and that 20% or more changes in the rate–pressure product did not improve predictions based on MAP alone. Urban et al. [16] also concluded that intraoperative hemodynamic changes, including heart rate, were not good indicators of myocardial ischemia.

Conversely, according to Slogoff and Keats [2], when a heart rate of 100 bpm or more continuing for more than 4 min during a coronary artery bypass graft (CABG) was defined as tachycardia, 40.6% of the intraoperative tachycardia was associated with ischemia (ST-segment depression of 0.1 mV or more on ECG). They also reported that in a group of patients who had a maximum heart rate of more than 110 bpm during an operation, the presence of intraoperative ischemia was more frequent than in a group who had a maximum heart rate of less than 110 bpm (63% *vs* 32%) [5]. Postoperative myocardial infarction was found more frequently in patients showing intraoperative ischemia than in those without it (6.9% *vs* 2.5%) [2]. Rao et al. [17] also reported that in noncardiac surgical patients, myocardial reinfarction occurred in the perioperative period in 5 of 24 patients who exhibited a heart rate increase of 20% or more for more than 5 min during the operation compared with the value before the induction of anesthesia. Smith et al. [18] reported that tachycardia persisting at a high level after CABG might be related to ischemia, and so a detailed examination would be necessary. A similar tendency was observed in the present study, in that heart rates observed at the completion of the operation and 12 h after the operation were rather high in patients with ECG alterations (see Table 4).

In both cardiac and noncardiac surgery, intraoperative tachycardia is shown to be related to intraoperative ischemia [19]. The data in the present study suggest that intraoperative tachycardia is related to postoperative ECG alterations. The incidence of postoperative ECG alterations was significantly greater when the intraoperative heart rate exceeded 1.2 IHR ($143 - 0.7 \times \text{Age}$) for 30 min and 1.3 IHR ($151 - 0.7 \times \text{Age}$) for 5 min. The age-corrected tachycardia showed a better correlation with the incidence of postoperative ECG alterations. Postoperative ECG alterations did not correlate with the MB fraction of creatine kinase in the serum collected 12 h after the operation.

References

1. Jose AD, Collison D (1970) The normal range and determinants of the intrinsic heart rate in man. Cardiovasc Res 4:160–167
2. Slogoff S, Keats AS (1985) Does perioperative myocardial ischemia lead to postoperative myocardial infarction? Anesthesiology 62:107–114
3. Knight AA, Hollenberg M, London MJ, Tubau J, Verrier E, Browner W, Mangano DT, The Study of Perioperative Ischemia Research Group (1988) Perioperative myocardial ischemia: importance of the preoperative ischemic pattern. Anesthesiology 68:681–688
4. London MJ, Tubau JF, Wong MG, Layug E, Hollenberg M, Krupski WC, Rapp JH, Browner WS, Mangano DT, The Study of Perioperative Ischemia Research Group (1990) The "natural history" of segmental wall motion abnormalities in patients undergoing noncardiac surgery. Anesthesiology 73:644–655
5. Slogoff S, Keats AS (1988) Does chronic treatment with calcium entry blocking drugs reduce perioperative myocardial ischemia? Anesthesiology 68:676–680
6. Stühmeier KD, Mainzer B, Sandmann W, Tarnow J (1992) Isoflurane does not increase the incidence of intraoperative myocardial ischemia compared with halothane during vascular surgery. Br J Anaesth 69:602–606
7. Zakowski MI, Ramanathan S, Baratta JB, Cziner D, Goldstein MJ, Kronzon I, Turndorf H (1993) Electrocardiographic changes during cesarean section: a cause for concern? Anesth Analg 76:162–167
8. Campeau L (1976) Grading of angina pectoris. (Letter). Circulation 54:522–523
9. Slogoff S, Keats AS, David Y, Igo SR (1990) Incidence of perioperative myocardial ischemia detected by different electrocardiographic systems. Anesthesiology 73:1074–1081
10. Mangano DT, Browner WS, Hollenberg M, London MJ, Tubau JF, Tateo IM, The Study of Perioperative Ischemia Research Group (1990) Association of perioperative myocardial ischemia with cardiac morbidity and mortality in men undergoing noncardiac surgery. N Engl J Med 323:1781–1788
11. Breslow MJ, Miller CF, Parker SD, Walman AT, Rogers MC (1986) Changes in T-wave morphology following anesthesia and surgery: a common recovery-room phenomenon. Anesthesiology 64:398–402

12. Irish CL, Manninen PH, Gelb AW (1988) Perioperative electrocardiographic changes in a surgical population. Can J Anaesth 34:s83–s84
13. Parsloe MR, Wyld R, Reilly CS, Nimmo WS (1989) Electrocardiographic changes after surgery. Br J Anaesth 63:229
14. Parsloe MRJ, Wyld R, Fox M, Reilly CS (1990) Silent myocardial ischemia in a patient with anaemia before operation. Br J Anaesth 64:634–637
15. Charlson ME, MacKenzie CR, Gold JP, Ales KL, Topkins M, Fairclough GP, Shires GT (1989) The preoperative and intraoperative hemodynamic predictors of postoperative myocardial infarction or ischemia in patients undergoing noncardiac surgery. Ann Surg 210:637–648
16. Urban MK, Gordon MA, Harris SN, O'Connor T, Barash PG (1993) Intraoperative hemodynamic changes are not good indicators of myocardial ischemia. Anesth Analg 76:942–949
17. Rao TLK, Jacobs KH, El-Etr AA (1983) Reinfarction following anesthesia in patients with myocardial infarction. Anesthesiology 59:499–505
18. Smith RC, Leung JM, Mangano DT, The Study of Perioperative Ischemia Research Group (1991) Postoperative myocardial ischemia in patients undergoing coronary artery bypass graft surgery. Anesthesiology 74:464–473
19. Mangano DT (1990) Perioperative cardiac morbidity (Review article). Anesthesiology 72:153–184