Title: **AUTOMATIC CONTROL OF ARTERIAL PRESSURE IN THE OPERATING ROOM: SAFETY DURING EPISODES OF ARTIFACT AND HYPOTENSION ?**

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Introduction. Servo controllers can assist in many functions in the operating room (OR), such as infusing drugs or regulating ventilation, and are becoming more common as useful assistants to the anesthetist. A controller can be valuable in and of itself, yet dangerous to the patient if it cannot distinguish between signal and noise. We have tested a sodium nitroprusside (SNP)-blood pressure control system in the OR during cardiac surgery. This report examines the ability of that controller to differentiate artifact from sudden real changes in mean arterial pressure (MAP).

Methods and Materials. The arterial pressure waveform was digitized at a rate of 20 Hz with a MetaResearch A-to-D converter. The MAP was calculated from the digitized signal and sampled by the controller each 2 seconds. The controller, implemented on Macintosh Plus computer, used a proportional-integral (PI) control scheme[1] that adjusted the SNP infusion rate by watching both the difference between the MAP and the desired pressure (Pd) and the integral of that difference. The controller adapted to changes in patient sensitivity by comparing the patient's response to the infusion with that of 9 models, each reflecting a different patient's sensitivity to SNP. The control algorithm had 30 safety features built into it, one of which we describe in this abstract. This feature is intended to identify the artifact arising from sampling blood from or flushing the arterial line and differentiate it from real changes in the patient's MAP. Artifact was diagnosed by the controller if the difference in MAP between successive samples exceeded 10 mm Hg twice or more in a 30-second interval. We studied 19 patients undergoing cardiac surgery, after institutional Review Board Approval and individual written consent were obtained. Preanesthetic medication varied, usually consisting of morphine and scopolamine. Anesthesia was induced and maintained with high-dose fentanyl. Monitoring consisted of a 5-lead ECG, arterial pressure, CVP, pulmonary arterial pressure, and a 2-lead EEG. Starting immediately after transport of the patient to the OR, the anesthetic team in charge of the case was asked to continually asses whether it was appropriate or necessary to use SNP to treat hypertension. When the team decided it was appropriate, the controller was started and informed of the desired MAP (Pd). After a learning period of about 6 min, the controller tried to maintain MAP within ±5 mm Hg of Pd. Each study was continuously attended by an investigator, and all events entered in a log, along with the time shown on the on-line controller graph. Data from the control period were printed out as charts of MAP and SNP infusion rate as a function of time. Each artifact in pressure measurement and each hypotensive episode was identified on the chart. A hypotensive episode was defined as any episode of 10 sec or more duration in which the MAP started within or above a ±5 mm Hg bound around Pd and then fell to 10 mm Hg or more below Pd.

Results: In the 19 patients analyzed, control was maintained for a total of 61 hours. Table 1 summarizes the data. The controller was designed to respond to hypotension by either reducing the infusion rate (mild hypotension) or stopping the infusion completely (severe hypotension). 178 episodes of sudden hypotension occurred, and the controller responded appropriately to 165 (93%) of them. In 13 instances (7%) the hypotension was interpreted as artifact and the infusion rate was held constant until the controller recognized that the hypotension was real. The longest period that elapsed between a mistaken artifact determination and an appropriate response to hypotension was 90 sec. 103 episodes of artifact occurred, for a mean of 5 per case. Of these 97 (94%) were correctly detected as artifact. In 6 instances (6%) the artifact was interpreted as a real pressure change and treated by a change in the infusion rate of SNP. In 4 of these the controller recognized the return of signal following the artifact and readjusted the infusion rate itself. In two instances the controller's response to the artifact was judged sufficiently inappropriate to require the investigator to intervene manually to reduce the infusion rate.

Discussion. A control system, like any other piece of equipment, should not be left unattended in the OR. In the two areas that we tested, the controller performed satisfactorily but not perfectly. It was correct 94% of the time in artifact detection, and it responded correctly to hypotension 93% of the time. Improved artifact detection would improve performance considerably but would not diminish the fact that vigilance by the anesthetist during periods of artifact on the arterial line was necessary for completely safe operation. The potential benefit of the 163 instances in which the controller responded appropriately to hypotensive episodes (during which a distracted user might have failed to lower the infusion rate) has not been evaluated. The anesthetic team viewed the controller as a useful clinical tool and felt that the performance of such a device deserved to be compared with that of an anesthetist controlling an infusion pump.

Reference:
1. Martin JF, Schneider AM, Smith NT: Multiple-model Adaptive Control of Blood Pressure Using Sodium Nitroprusside. IEEE Trans on Biomedical Engineering BME-34, no. 8: 603-611, 1987

RESPONSE TO ARTIFACT AND DROPPING MAP

CASE	hours controlled	flushes	correct dx	MAP drops	SNP off	SNP reduced	SNP constant
1	4.2	8	8	5	2	2	1
2	2.6	3	2	4	3	0	1
3	3.1	5	5	15	5	10	0
4	2.8	5	5	10	7	3	0
5	4.4	3	3	12	7	3	2
6	4.3	3	3	10	9	1	0
7	5.5	6	6	12	8	3	1
8	0.6	1	1	2	2	0	0
9	1.2	3	2	7	5	2	0
10	5.0	6	6	17	11	6	0
11	1.2	3	3	4	0	1	3
12	2.8	5	4	21	12	7	2
13	1.4	2	2	0	0	0	0
14	3.6	16	16	12	4	7	1
15	4.4	4	4	9	7	2	0
16	2.9	6	6	10	5	4	1
17	1.2	7	7	9	4	5	0
18	5.9	11	8	9	4	5	0
19	4.3	6	6	10	5	4	1
total	61.0	103.0	97	178	100	65	13
ave/case	3.2	5.4	5.1	9.4	5.3	3.4	0.7
std dev	1.6	3.5	3.4	5.1	3.3	2.7	1.9
per cent			94.2		56.2	36.5	7.3

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