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Comparison of the automated Dinamap blood pressure monitor with the mercury sphygmomanometer for detecting hypertension in the day case pre-assessment clinic

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Abstract

Patients will be rejected from surgery by nurse-led pre-assessment clinics and will need to be assessed by their general practitioners if their blood pressure is higher than a pre-determined value. We have assessed the accuracy of the Dinamap automatic blood pressure recorder compared with manual mercury sphygmomanometry for detecting pre-operative hypertension in the day case pre-assessment clinic under everyday conditions. Two hundred consecutive patients attending for day case surgery pre-assessment had their blood pressure measured using the automated and the manual methods. We found that the Dinamap over-read systolic blood pressure by a mean of 8.38 mmHg and under-read diastolic pressure by a mean of 1.68 mmHg when compared with manual readings. Of the patients 6.5% would have been inappropriately diagnosed as hypertensive using the Dinamap and thus potentially rejected from day surgery and inappropriately referred to their general practitioner.

Keywords: Arterial pressure; Measurement; Equipment; Automatic and manual sphygmomanometers

1. Introduction

Hypertension causes significant morbidity and requires treatment before elective anaesthesia [1,2]. In our day surgery unit patients are pre-assessed by the nursing staff and part of this process is measurement of blood pressure. Exclusion from surgery is based on detecting hypertension, as defined by our Day Surgery Unit protocol, using an automated blood pressure machine. Rejection results in referral back to the general practitioner (GP) for assessment. We have been contacted on numerous occasions by GPs who have subsequently found many of these patients to be normotensive on manually measuring the blood pressure. Any disparity of readings between general practice and the Day Surgery Unit can cause confusion and delays in surgery.

The automated blood pressure monitor has been shown to be reliable as a trend monitor in anaesthesia [3]. The ability of automated blood pressure monitors to give accurate, single blood pressure measurements has only been investigated compared to manual sphygmomanometry in pregnant women [4], children [5], 50–54 year olds [6], known hypertensive patients [7] and diabetics [8]. It has not been assessed for accuracy in the heterogeneous population that presents for day surgery. Manual measurement of blood pressure using the mercury sphygmomanometer may be used to recheck raised blood pressure in the clinic, but there has been no published data to confirm its usefulness in this setting.

This study was performed to determine whether the automated monitor accurately detected hypertension in the pre-assessment clinic and thus appropriately excluded patients from day surgery.

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2. Method

The study population consisted of 200 consecutive patients attending the nurse led pre-assessment clinic for day case surgery. Approval for the study was obtained from the Medical Ethics Committee. All patients were over 16 years old and were classified as ASA 1 or 2. The patients were assessed in the same room using a procedure for pre-operative assessment that is standard in our hospital. A questionnaire assessment taking, on average, 15 min was completed with the patient resting in an armchair. Blood pressure was then measured with the patient remaining seated. All patients had readings taken with the manual mercury sphygmomanometer and the automated Dinamap (model 8100) vital signs monitor (Critikon), with the order of use being determined randomly. The same arm and appropriate cuff size were used for both methods with the patient sitting comfortably and the arm relaxed on a supportive pillow.

Nurses who routinely carry out this task performed the pre-assessments. Blood pressure was taken manually following the guidelines of the British Hypertension Society using the phase 5 diastolic pressure [9]. Both measuring devices were calibrated before starting the study.

The mean differences between manual and Dinamap readings were analysed using the paired t-test. Regression analysis was also performed to assess the correlation between the two forms of blood pressure recording and in order to see whether a predictive equation could be produced. The R^2 value gives an indication of the degree of fit of the line, with a value of one indicating a total fit, and a value of zero indicating no correlation. $P < 0.05$ was considered significant.

The sample size of 200 gave a power of 75% to detect a 5 mmHg difference in systolic pressure and a power of over 95% to detect the same difference in diastolic pressure with a type 1 error rate of 0.05.

3. Results

The characteristics of the patients studied are shown in Table 1.

Table 1
Patient characteristics—mean (S.D.) or percentage

Age (years)	46.3 (16.8)
Sex (M:F)	102:98
Weight (kg)	74.3 (13)
Height (cm)	170.1 (9.6)
Treated hypertensive (%)	11
Ischaemic heart disease (%)	5
Diabetes mellitus (%)	0.5
Smoker (%)	29.5

The mean difference between manual and Dinamap readings was -8.38 mmHg (95% confidence intervals -6.8–-9.96, $P \ll 0.001$) for systolic pressure and 1.68 mmHg (95% confidence intervals 0.42–2.94, $P < 0.01$) for diastolic pressure. When the data was divided into two groups according to the first method of blood pressure measurement (manual first or Dinamap first) it was found that there was no significant difference between the two groups ($P = 0.56$ for systolic pressure and $P = 0.71$ for diastolic pressure). Comparing patients with or without known hypertension, there was no significant differences between the manual and Dinamap mean differences in the two groups for systolic or diastolic pressure ($P = 0.71$).

The scatter diagrams for systolic and diastolic measurements are shown in Figs. 1 and 2. The regression lines and R^2 values are shown, where y is the predicted manual reading and x is the Dinamap reading.

Plots of the difference between the two measurements against the average measurement are shown in Figs. 3 and 4 for systolic and diastolic readings, respectively, according to the method of Bland and Altman [10]. The limits of agreement between the two methods (mean of the difference (manual minus Dinamap) ± 2 S.D.) were -31.1 to $+14.3$ mmHg for systolic, and -16.5 to $+19.8$ for diastolic blood pressure measurements (represented by the broken horizontal lines). The mean differences (-8.38 and 1.68 mmHg for systolic and diastolic measurements, respectively) are represented by continuous horizontal lines.

Table 2 shows the number of patients who had raised blood pressure (systolic pressure greater than 200 mmHg and/or diastolic pressure greater than 110 mmHg) who would have been excluded automatically from day surgery. Table 3 shows the number of patients who had a less extreme elevation of blood pressure (systolic pressure between 160 and 200 mmHg and/or diastolic pressure between 95 and 110 mmHg). None of these patients had known ischaemic heart disease that would have automatically excluded them from immediate day surgery.

4. Discussion

The measurement of blood pressure at the pre-assessment clinic is one of the factors that will determine suitability for day surgery. This study has shown that in our day surgery unit, the automated blood pressure recording is, on average, approximately 8 mmHg greater than the manual systolic reading and 2 mmHg less than the manual diastolic reading. Both results are statistically significant ($P \ll 0.001$ and $P < 0.01$, respectively).

The regression line on the scatter diagram for diastolic measurements shows a trend for the Dinamap to over-read at higher pressures, and under-read at

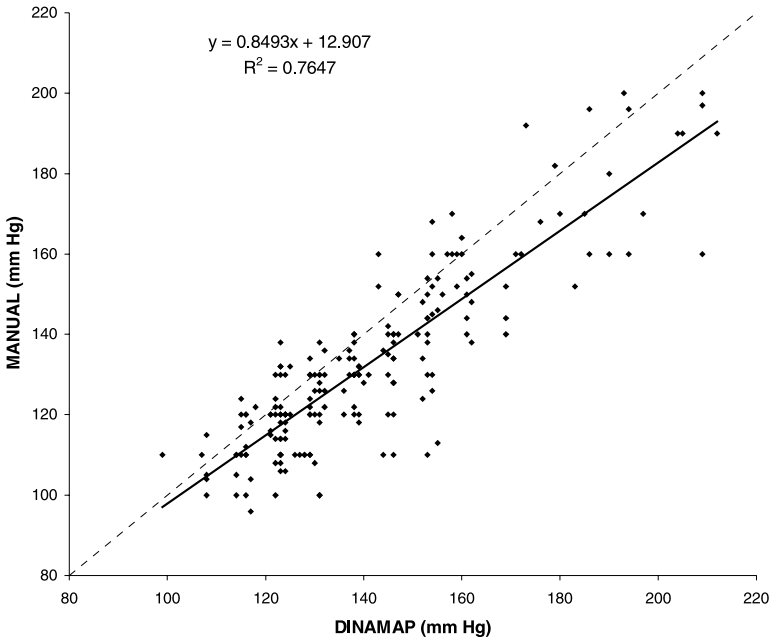

Fig. 1. Scatter diagram and regression line (bold) for systolic blood pressure readings, with line of identity (dotted).

lower pressures with a crossover point at 83 mmHg. Despite an average error of −2 mmHg over the whole range of pressures in this study (47–124 mmHg), at the significant clinical pressures (> 95 mmHg) the error is much larger and is likely to result in inappropriate cancellation if the blood pressure is not checked manually.

The regression line for systolic pressure measurement shows a similar trend with a crossover point at 86 mmHg. At significant clinical pressures (> 160 mmHg) the systolic error (averaging 8 mmHg over the whole range 99–212 mmHg) is likely to be proportionately greater than the diastolic error, resulting in a greater number of inappropriate cancellations if the systolic pressure is not checked manually.

The World Health Organisation criterion for normotension is a blood pressure less than 140/90 and for hypertension a blood pressure greater than 160/95 [11].

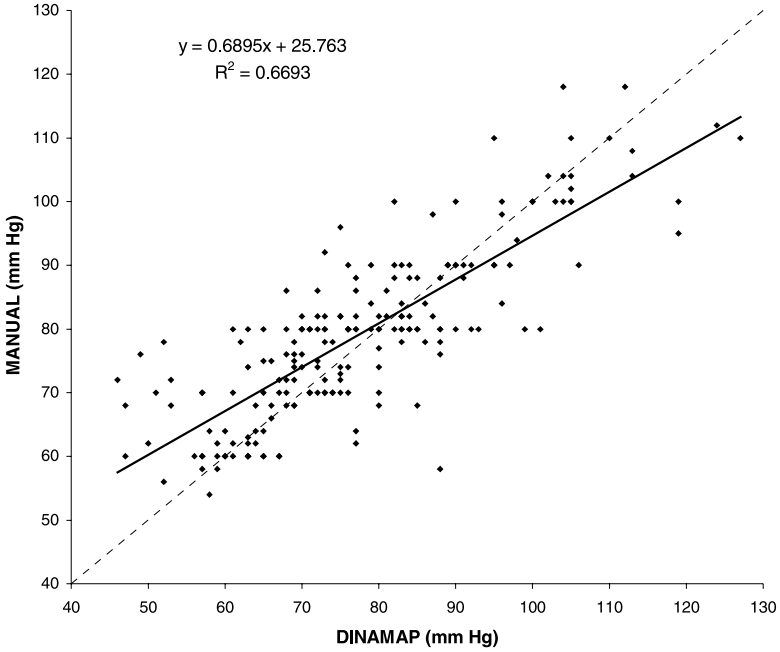

Fig. 2. Scatter diagram and regression line (bold) for diastolic blood pressure readings, with line of identity (dotted).

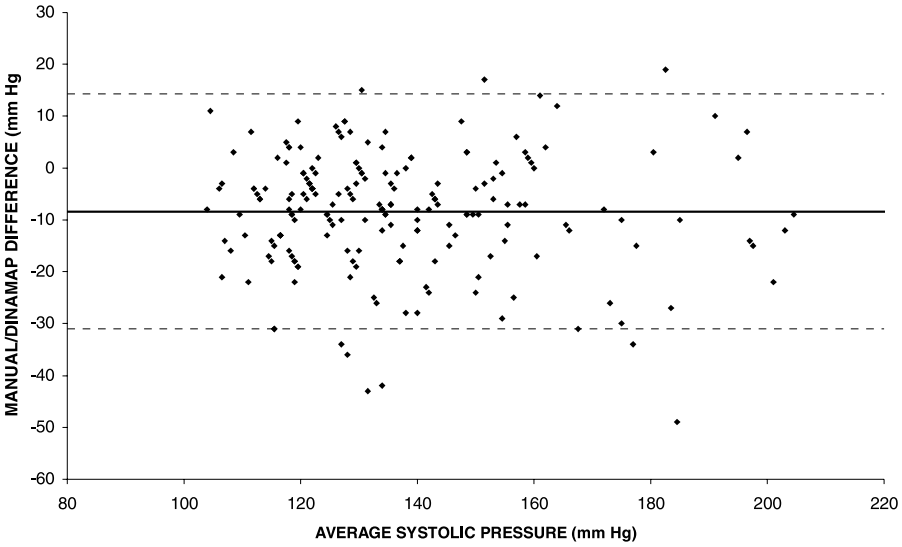

Fig. 3. Plot of the difference between manual and Dinamap systolic measurements against average systolic pressure, with mean of differences (bold line) and 95% limits of agreement (broken lines).

Table 2
Number of patients with raised blood pressure (BP greater than 200/110) at pre-assessment according to the detection method

	Method of detection		
	Dinamap alone	Manual alone	Both
Systolic hypertension	3 (1)	0	0
Diastolic hypertension	3 (2)	1 (1)	2 (1)
Systolic and diastolic hypertension	2 (2)	0	0

Number of these with known hypertension in brackets.

Recommendations are that treatment should start in middle age if either systolic is greater than 160 mmHg or diastolic is greater than 95 mmHg [12].

Anaesthesia in untreated hypertensive patients can result in well-recognised hazards [1,2]. Although controlled hypertension in otherwise fit patients does not make the patient unsuitable for day surgery, the level at which the blood pressure is perceived to be controlled is difficult to determine [13]. It has been suggested that elective surgery should be cancelled for patients with diastolic arterial pressures exceeding 110 mmHg [14]. Mild hypertension should be controlled but even this may not influence mortality [15].

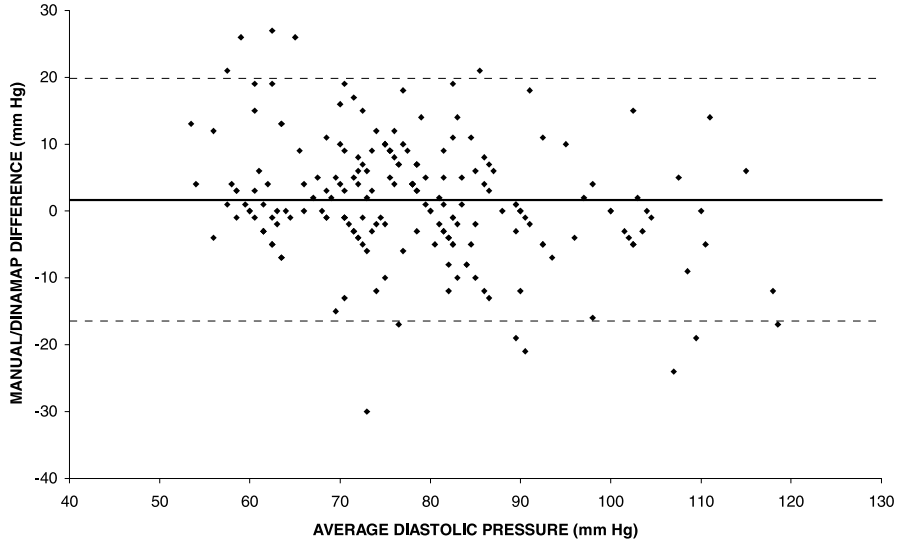

Fig. 4. Plot of the difference between manual and Dinamap diastolic measurements against average systolic pressure, with mean of differences (bold line) and 95% limits of agreement (broken lines).

Table 3
Number of patients with raised blood pressure (BP between 160/95 and 200/110) at pre-assessment according to the detection method

	Method of detection		
	Dinamap alone	Manual alone	Both
Systolic hypertension	10 (2)	0	4 (3)
Diastolic hypertension	2 (0)	4 (0)	7 (2)
Systolic and diastolic hypertension	4 (0)	0	4 (2)

Number of these with known hypertension in brackets.

In our unit patients with raised blood pressure (diastolic pressure greater than 95 mmHg and/or systolic pressure greater than 160 mmHg) after resting 15 min will not be immediately suitable for day surgery. Those patients with diastolic pressures greater than 110 mmHg and/or systolic pressures greater than 200 mmHg are referred back to their GP for stabilisation. The patients with intermediate raised blood pressure will only be booked for surgery if otherwise fit and they have their blood pressures checked regularly by their GPs and they know it is usually normal. The other patients will be refused immediate day surgery until the GP has rechecked blood pressure and is happy that it is normal.

In the study 46 patients (23%) were defined as having hypertension by one or both methods of measurement. Eleven patients would have been immediately refused day surgery because of blood pressures greater then 200/110. Of these, two patients had their hypertension detected by both methods. One patient was found to be hypertensive by manual measurement only and may have been inappropriately admitted for day surgery. The remaining eight patients were only detected using the Dinamap monitor and so would have been inappropriately excluded from day surgery, had their blood pressures not been checked manually. Within the group of patients found to have less severely raised blood pressure, there were 12 patients who would have been excluded because they had not had their blood pressure previously checked. Of these, five were detected to have hypertension by both measurement methods, two would have been missed if the Dinamap was used alone and five would have been inappropriately excluded if the blood pressure had not been checked by manual measurement.

Overall these results represent a potential 6.5% inappropriate exclusion rate and 1.5% inappropriate inclusion rate. Using both methods of measurement, we have a 5% rate of appropriate referral back to the GP from day surgery because of hypertension.

Bland and Altman [10] have shown that plots of difference in measurements against average provides the most meaningful information regarding the accuracy of the mean difference and standard deviation over the measured range. These graphs for systolic and diastolic pressures both show a trend in bias with a tendency for the mean difference to increase (i.e. the Dinamap reading becomes greater) with increasing magnitude of pressure. For systolic readings this is a very small trend with a weak relationship as there is large scatter of results. The diastolic plot shows a greater trend in difference with increasing magnitude. However the scatter is still wide with a weak correlation.

In the present study the correlation between the two methods was not very high (R^2 0.77 for systolic pressure and 0.67 for diastolic pressure). It would be expected that there would be high correlation between the two methods as they are both designed to measure the same variable. The wide limits of agreement between the two methods shown in Figs. 3 and 4 reveal a considerable degree of variability. There are obvious sources of variability within the study. Although the number of nursing staff participating in the study was limited, several day unit nursing staff were used for pre-assessment and, therefore, despite pre-study training in the protocol for blood pressure measurement, there could still be inter-individual observer error. This study reflects what is the standard practice of the day unit with all its consequences. There was greater potential for observer bias when performing the measurement owing to the fact that the nurse taking the second reading was not blinded to the first result. This would have had little potential for bias when the second reading was automated, but when the second reading was manual the result may have been influenced by the known Dinamap reading. A comparison of the two sets of data according to the order of the two measurements shows only a very small numerical difference (<1 mmHg for systolic and <0.5 mmHg for diastolic pressures) and no statistically significant difference between the two groups. The Hawksley random-zero sphygmomanometer has been used for many years to assess the accuracy of blood pressure monitors because of its apparent ability to blind the observer to the actual pressure reading until after it has been measured. More recent data has shown that this apparatus is consistently inaccurate when compared to the standard mercury sphygmomanometer [16]. It has been suggested that the random-zero sphygmomanometer should not be used any more in blood pressure trials and that the standard mercury sphygmomanometer should be the gold standard. The latter machine was used in this trial.

Inappropriate cuff size and different arm position would affect readings [17,18] but in the study the same, appropriate cuff size was used for both measurements and with the arm in the same position.

Unlike previous studies comparing automatic with manual readings, a heterogeneous group of patients of various ages and disease range including known hyper-

tensives was studied. As the automated method was compared with the manual method of measurement in each patient, these factors should not have biased the results. Indeed we were particularly interested in investigating measurement errors in such a varied population that attends for day surgery.

It is common practice for blood pressure to be rechecked using the same method of measurement if hypertension is detected. In our study only single readings with each method were used. In the study of Bassein et al. [7], three measurements using each method were used and they found that the first reading was always significantly higher than the subsequent two. Some people find the Dinamap more uncomfortable than the manual method and this could have biased the results. By randomly varying the measurement method used first, we hoped to remove any bias that may have been present due to this first measurement phenomenon. Mancia [19] studied the alarm reaction of doctors on blood pressure measurement. He showed that this 'hypertensive' reaction peaks at 4 min and has returned to normal by 10 min after first approach of the doctor. There is a similar but milder reaction to nurses. In our study, blood pressure was not taken until approximately 15 min into the consultation, which should have removed this alarm effect.

There are of course great fluctuations in blood pressure over a 24-h period [20] and even within a short period of time, so this could contribute to error, but again 15 min of resting should have reduced this to a minimum.

Although the criteria for definition of hypertension are fixed, the decision to treat will be based on a series of readings over time (days rather than minutes). In nurse run pre-assessment clinics, strict guidelines need to be laid down for acceptance for surgery. The study shows a significant rejection rate on the basis of hypertension by definition, though how many of these ultimately require treatment is unknown. It is important to identify patients with potential clinical hypertension even if they are not undergoing anaesthesia as it has been shown that reducing blood pressure is important both in middle aged and elderly people to reduce vascular events [12,21]. Treatment trends have tended to be to lower pressure to the 160/90 level. Recent work has suggested that reducing the diastolic pressure to at least 83 mmHg will produce further benefit [22].

In conclusion, we have found that although the automated Dinamap blood pressure reading will be clinically reliable at normotensive values, the error, particularly for systolic measurement, will increase at borderline hypertensive levels and higher. We would recommend that, in order to prevent patients being inappropriately refused day surgery, blood pressure should be rechecked using a manual sphygmomanometer if the Dinamap gives a hypertensive reading.

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