

Are Aneroid Sphygmomanometers Accurate in Hospital and Clinic Settings?

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Background: The aneroid sphygmomanometer is commonly used for the indirect measurement of blood pressure despite significant concerns about its accuracy. Although the mercury sphygmomanometer is highly accurate, there are concerns about the environmental toxicity of mercury. In response to various external pressures to become essentially mercury free, the Mayo Clinic, Rochester, Minn, has replaced many mercury sphygmomanometers with aneroid devices. Since 1993, a maintenance protocol has been in place to ensure proper function and accuracy of these devices.

Methods: We assessed the accuracy of 283 aneroid devices using as the reference standard a digital pressure and vacuum meter that was calibrated using a mercury sphygmomanometer.

Results: The mean \pm SD values from the aneroid device

in millimeters of mercury at each reference point (at 20-mm Hg intervals from 60 to 240 mm Hg defined by the reference device) were 59.9 ± 1.9 at 60; 79.9 ± 1.9 at 80; 100.0 ± 1.8 at 100; 120.3 ± 1.8 at 120; 140.7 ± 1.4 at 140; 160.7 ± 1.7 at 160; 180.9 ± 1.3 at 180; 200.7 ± 5.0 at 200; 221.0 ± 1.3 at 220; and 240.8 ± 1.6 at 240 ($r=0.99$; $P<.001$). The values from the aneroid device underestimated those of the reference device by a mean of 0.5 mm Hg (95% confidence interval, 0.3-0.7). Virtually 100% of the values from the aneroid device were within the 4-mm Hg range recommended by the Association for the Advancement of Medical Instrumentation.

Conclusion: Aneroid sphygmomanometers provide accurate pressure measurements when a proper maintenance protocol is followed.

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THE ANEROID sphygmomanometer has been used for the indirect measurement of blood pressure since the studies of Hill and Bernard in 1897¹ and has been widely used in clinical practice because of its convenience and portability. Compared with standard mercury sphygmomanometry, however, the aneroid device has more working parts and requires more maintenance, particularly when it is subjected to heavy use. This potential shortcoming has been emphasized in the report of Bailey et al,² who demonstrated that aneroid sphygmomanometers are significantly less accurate compared with mercury devices. These investigators concluded that "aneroid sphygmomanometers [should] be inspected for physical damage and validated for accuracy against a standard mercury manometer at 6-month intervals to prevent inaccurate blood pressure measurements."

Concern about the accuracy of the aneroid sphygmomanometer notwithstanding,

apprehension regarding the potential environmental toxicity of mercury³⁻⁵ has led to increased interest in mercury-free methods of blood pressure measurement.⁶ This phenomenon has occurred despite the lack of evidence of injury resulting from a sphygmomanometer-related mercury exposure in the health care setting,⁷ except under very extreme or unusual circumstances.⁸

During 1993-1998, increasing pressure from state regulatory and licensing agencies (regarding hazardous waste handling and removal) and a review of our institutional experience with mercury spills led to the replacement of mercury sphygmomanometers with aneroid devices throughout our inpatient facilities and several outpatient clinical areas. A regular maintenance program was developed and implemented. The focus of this study was to assess the accuracy of a sample of aneroid sphygmomanometers since the implementation of a regular maintenance protocol.

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METHODS

Since 1993, approximately 1500 mercury sphygmomanometers were replaced with wall-mounted aneroid devices at the 2 principal inpatient areas of the Mayo Clinic (Saint Marys Hospital and Rochester Methodist Hospital), Rochester, Minn. At the same time, the following protocol was developed in conjunction with the Division of Hypertension and in accordance with the standards published by the Association for the Advancement of Medical Instrumentation.⁹ This protocol was incorporated into an annual inspection of additional patient-related medical devices in all patient care areas, including medical and surgical nursing units, critical care units, surgical units, and radiology procedure areas. The protocol was performed by a biomedical equipment maintenance technician following instruction and initial observation by a member of the Division of Hypertension (P.L.J.).

PROTOCOL

1. All aneroid devices were visually inspected for damage to the instrument case, wall mount, bracket, and extension hose.
2. The sphygmomanometer needle should be set to zero prior to inflation.
3. A digital pressure and vacuum meter (Digimano, Netech Corp, Hicksville, NY) was used as the reference standard. This device was checked for accuracy against a mercury sphygmomanometer twice yearly by the biomedical equipment maintenance technician and was also checked by the manufacturer once yearly. When checked for accuracy against a mercury sphygmomanometer set to zero throughout the pressure range of 60 to 240 mm Hg, the digital reference device underestimated the former by 0.12 mm Hg (95% confidence interval, 0.00-0.24). Subsequently, a Y tube was used to connect the inflation bulb to the reference and aneroid devices. The tube was then inflated to 240 mm Hg on the reference device and the corresponding value on the aneroid device was recorded. The system was then deflated in increments of 20 mm Hg to a lower limit of 60 mm Hg with corresponding values from the aneroid device taken at each interval.
4. Any aneroid sphygmomanometer that appeared physically damaged, did not read zero prior to inflation, or whose reading differed from that of the reference device by greater than 4 mm Hg was replaced with a new, properly functioning device.

STATISTICAL ANALYSES

Statistical analyses were performed using a database (Excel; Microsoft Corp, Redmond, Wash) and statistical program with additional analyses according to the method of Bland and Altman.¹⁰

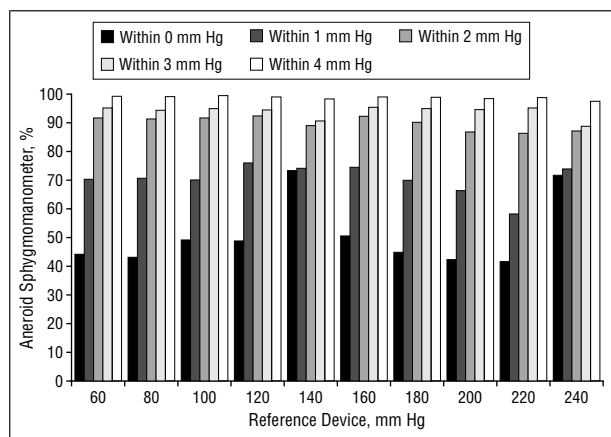
Aneroid sphygmomanometer data were collected prospectively from Saint Marys Hospital (n=155) and Rochester Methodist Hospital (n=93) from January 1, 1999, to April 30, 1999. This sample represented approximately 17% of the 1500 aneroid sphygmomanometers installed at the 2 hospitals since 1993 and was collected as part of the routine maintenance program as described previously. In addition, aneroid sphygmomanometers (n=35) from several outpatient areas not covered by the above maintenance protocol were randomly chosen to be inspected. With the exception of 1 device, all the devices from the inpatient areas read zero prior to inflation and demonstrated smooth needle movement throughout the range of measurements from 240 mm Hg to 60 mm Hg. The 1 device was replaced during the study. In the outpatient departments, 3 devices (9%) were replaced because 1 or more readings differed from the reference device by more than 4 mm Hg (mean±SD, 4.9±0.9 mm Hg). When these latter 3 devices were excluded, there were no significant differences in accuracy between the inpatient and outpatient aneroid sphygmomanometers (data not shown).

Mean±SD pressure values in millimeters of mercury from the aneroid devices at each reference point (defined by the reference device) were 59.9±1.9 at 60; 79.9±1.9 at 80; 100.0±1.8 at 100; 120.3±1.8 at 120; 140.7±1.4 at 140; 160.7±1.7 at 160; 180.9±1.3 at 180; 200.7±5.0 at 200; 221.0±1.3 at 220; and 240.8±1.6 at 240. The values from the aneroid device were virtually identical in the intervals between 60 mm Hg and 240 mm Hg ($r=0.99$; $P<.001$). The values from the aneroid device underestimated those of the reference device by a mean of 0.5 mm Hg (95% confidence interval, 0.3-0.7). Virtually 100% of the values from the aneroid device were within 4 mm Hg of the reference device (**Figure**).

COMMENT

The results of this study demonstrate that aneroid sphygmomanometers provide accurate pressure determinations when compared with a digital pressure and vacuum meter. The performance of the aneroid sphygmomanometers was well within the accuracy guidelines of 3 to 4 mm Hg as recommended by several authors.¹¹⁻¹⁴ This finding contradicts the results of several previous studies.^{2,13} The contribution of a routine maintenance regimen in assuring accuracy of aneroid sphygmomanometers is suggested by better performance of the inpatient devices compared with the outpatient devices that were not part of the maintenance protocol (1 of 248 inpatient devices were replaced vs 3 of 35 outpatient devices replaced). A potential strength of this study is that the data were collected as part of an ongoing maintenance program and were not a random prospective sample that could have been biased by the inclusion or exclusion of recently inspected aneroid devices.

Routine maintenance of sphygmomanometers may not be widespread. In a survey¹⁵ conducted in general practitioners in England, only about 50% had serviced their



Cumulative percentage of values using an aneroid sphygmomanometer that were within 0 to 4 mm Hg of values using a digital pressure and vacuum meter as a reference ($n=283$).

devices within 1 year and 24% of devices had never been serviced (over a mean of 6 years). While the present study was limited to the evaluation of fixed, wall-mounted aneroid sphygmomanometers, there is no a priori reason to suspect that a similar maintenance protocol could not apply to more portable devices, such as those that are handheld or attached to the blood pressure cuff. Indeed, these latter devices are more susceptible to damage from everyday use and are more likely to need periodic inspection.

The mercury column sphygmomanometer has remained the gold standard of indirect blood pressure measurement for many years. In our experience and we suspect in that of most clinicians, it has provided trouble-free service, other than the occasional need for calibration and replacement of worn tubing or cuffs. Unfortunately, the potential environmental toxicity of mercury, whether real or imagined, has led to increased interest in mercury-independent measurement of blood pressure. We were somewhat surprised when we reviewed the Mayo Clinic experience with mercury spills from October 1, 1993, to November 30, 1995. During this time, 50 spills were documented related to leakage from sphygmomanometers. Several of these spills resulted from physical abuse to the device by unruly patients, children, or patients with dementia or other psychiatric problems. The cleanup costs were \$26 000, not including time lost from temporary unavailability of the clinical area. Use of a digital pressure and vacuum meter as a reference device has also reduced the need to maintain a large number of mercury sphygmomanometers for maintenance checks of the aneroid devices. We have found that these reference devices are accurate, easy to use, and relatively inexpensive at \$250 to \$500, depending on the specific model.

Additional pressures on health care institutions have come from state regulatory agencies that can restrict access to or needed expansion of biomedical

waste disposal facilities if an institution is not mercury free. In addition, these agencies have mandated that hospitals provide detailed inventories of existing mercury supplies in any form. However, these proposed restrictions provide for the retention of a small number of mercury sphygmomanometers for calibration purposes. Financial considerations may limit conversion to aneroid devices and development of a regular maintenance program in some institutions currently using mercury sphygmomanometers. In these situations, the risk of mercury spills could be minimized by the selective use of aneroid devices in those settings associated with an increased risk of damage to equipment, such as pediatric areas and emergency departments.

In conclusion, a carefully maintained aneroid sphygmomanometer is an accurate and clinically useful means of indirect blood pressure measurement.

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