SUMMARY The cost-effectiveness of treating hypertension at the patient's place of work was compared in a randomized controlled trial with care delivered in the community. The average total cost per patient for worksite care in this 12-month study was not significantly different from that for regular care ($242.86 ± 6.94 vs $211.34 ± 18.66, mean ±SEM). The worksite health system cost was significantly more expensive ($197.36 ± 4.99 vs $129.33 ± 13.34, p < 0.001) but the patient cost was significantly less ($45.40 ± 3.23 vs $82.00 ± 6.20, p < 0.01). The mean reduction in diastolic blood pressure (BP) at the year-end assessment was significantly greater in the worksite group (12.1 ± 0.6 vs 6.5 ± 0.6 mm Hg, p < 0.001). The incremental cost-effectiveness ratio of $5.63 per mm Hg for worksite care was less than the base cost-effectiveness ratio of $32.51 per mm Hg for regular care, indicating that the worksite program was substantially more cost-effective. Our findings support health policies that favor allocating resources to work-based hypertension treatment programs for the target group identified in this study. (Hypertension 3: 211–218, 1981)

KEY WORDS • cost-benefit analysis • allied health personnel • ambulatory care • industrial medicine • delivery of health care • hypertension • occupational health services • patient acceptance of health care

As a solution to these problems, alternative medical care approaches to control hypertension have been developed. Although in most instances these approaches have been judged to be effective, safe, and acceptable, detailed economic analyses of these programs have not been published. The importance of such analyses is paramount now that the benefit of treating mild hypertension has been convincingly demonstrated, making it desirable to treat even larger numbers of people with available health resources. The randomized controlled trial reported here was undertaken to assess the cost-effectiveness of a work-based hypertension program in which all care for hypertension was provided onsite.

Methods
Participants in the trial were selected from 21,906 volunteers, aged 18 to 69 years, in 41 business locations in Metropolitan Toronto who were screened for hypertension in 1976–77. Those with an average fifth phase diastolic BP greater than 90 mm Hg on the sec-
and third readings were scheduled for a second screen 1 week later. At that time a nurse administered a brief eligibility questionnaire and took three more BP readings. Eligibility criteria were as follows: 1) mean diastolic BP at or above 95 mm Hg, or a mean diastolic BP between 91–94 mm Hg and mean systolic BP greater than 140 mm Hg; 2) intention to remain in employment for the year following entry into the study; 3) not on any treatment for hypertension for at least 3 months before screening; 4) not on other daily medications, oral contraceptives, or estrogen replacement therapy; 5) not pregnant nor planning to become so during the year of the study; and 6) no objections from the family physician. Those eligible and willing to participate were scheduled for a third screen and received two attitudinal questionnaires to be answered at the third session. At Session 3, additional BP readings were taken as well as baseline laboratory tests (hemoglobin, white blood cell count, urinalysis, serum electrolytes, serum creatinine, serum cholesterol, serum uric acid, blood glucose, and an electrocardiogram). Individuals who were still eligible by BP criteria and who had no evidence of remediable secondary forms of hypertension were given an explanation of the study and invited to sign a consent form, indicating their willingness to participate.

Participants were stratified for sex, median age, and median diastolic BP, and then randomly allocated within strata to treatment at the worksite (“worksite care”, WS) or in the community from physicians in private practice (“regular care”, RC). All WS patients were evaluated at entry by a physician to exclude complicating or concurrent problems, to establish a goal BP, and to initiate antihypertensive therapy. Long-term follow-up was provided at the worksite on company time by two nurses who were taught to manage hypertension according to a standard protocol18 and who reported to physicians of the Hypertension Service of the Mount Sinai Hospital in Toronto. An appointment with their own doctor was made for all individuals in RC groups. All screening data including the results of the baseline laboratory tests were enclosed in the referral letter to the family doctor. At 6 and 12 months after entry, all participants were assessed at work by a specially trained BP technician who was unaware of group allocation. A questionnaire was administered to determine medication status, and three BP readings were taken.

Medical Care Costs

These were itemized for each patient under health system and patient costs. Health system costs were those attributed to case-finding and treatment. Patient costs were those related to lost time from work or leisure and travel. Costs incurred before randomization (screening costs) were distributed equally across both groups. Treatment costs reflected actual difference in the costs generated by the two types of health care delivery. Costs are expressed in 1977 Canadian dollars.

Screening Costs

Costs for all who underwent any part of screening were included in the analysis. The costs involved in screening included personnel, equipment and supplies, travel, participants' time, and administrative costs. Personnel costs for screening comprised the salaries and fringe benefits of the five BP technicians and two nurses. For the latter, time was recorded prospectively on a weekly log, including travel, service, and office time, and was converted into monetary terms using their salaries and fringe benefits. The cost of the laboratory evaluation, which included the interpretation fee of the electrocardiogram by a cardiologist, was determined using the Ontario Medical Association fee schedule and was considered a personnel cost. Equipment used in the study included seven sphygmomanometers and stethoscopes and one electrocardiograph. Equipment costs were calculated using an annual depreciation rate of 16.75% on the purchase price (The Canadian Hospital Association's average annual depreciation rate for clinical equipment was used, as described in the Canadian Hospital Accounting Manual, 1968.) Cost of the participants' time was prorated according to hourly wages at the year-end assessment, and included waiting, service, and questionnaire completion time at screening visits. Actual wage values were obtained on 86.3% of the participants, and an average annual income was substituted for missing data (source of data was Statistics Canada). The administrative cost was estimated as 30% of the health system cost of the screening program and included arranging the screening operation, scheduling participants and technicians, printing, telephone, physical facilities, postage, and other such expenses.

Treatment Costs

Health system costs of treatment included the provision of care and laboratory examinations, hospitalization, and drugs. The source of payment for physician visits and laboratory examinations was the Ontario Government universal health insurance plan. Each participant had a contract number and, within a contract, services were sorted by date for all medical services received during the study year. For each claim, the service file identified the physician who provided the service, the specialty of the physician, the diagnosis specified by the physician, and/or the type of service provided and the amount paid. Diagnostic and therapeutic procedures, diagnostic radiology and laboratory tests were designated by specific codes. Only services properly identified as related to hypertension were included in cost calculations. The cost of the nurses' service was calculated from weekly logs by converting the total time spent in patient care activities (direct care, travel, and paper work related to patient care) into a dollar value according to their hourly wage. The cost of physician's time to supervise the nurses was added to the cost of the nurses' service and was calculated by converting total time spent into
a dollar value using the average net income and annual working hours of physicians in Ontario (source of data was the Ontario Medical Association). The total number of days of hospitalization per participant was obtained from the service file, and only those days used for diagnostic evaluation and management of hypertension, as determined by direct questioning at the year-end assessment, were included in the cost calculation. The average per diem cost of hospitalization in Ontario in 1977 was used to determine hospital cost rather than more elaborate methods because of the small numbers involved. Drug costs were determined from many of the insurance companies who sponsored drug insurance programs in industries involved in the study. Complete drug cost data were available for 36.6% of those in the WS group and 44.1% in the RC group on medication. Missing data were due to varying insurance company accounting practices at the different worksites rather than lack of patient cooperation. For those with no drug data (15.1% of those on medication), the average cost for those with complete data in each group was used. For the remainder with incomplete data, an individual average monthly drug cost was computed from available data, and this value was used for missing monthly data to calculate the total cost.

Patient cost for physician and laboratory services was calculated in the following fashion. Log forms, recording the distance travelled, and time spent in travel, waiting, and service for a single visit to the doctor's office or laboratory, were obtained from 95 RC and 82 WS patients. Time was converted into dollar value using the midpoint of the wage category to which the individual belonged, and travel costs were calculated by converting distance into dollars at the rate of 17 cents per mile. The total patient cost for single visits to the laboratory or doctor's office was then multiplied by the number of visits for these services by the individual during the study year, as determined from the health insurance plan contract file.

For individuals who did not complete single visit logs, patient cost was calculated as the product of their actual wage and visit frequencies times the average value for travel and time from the logs. In the WS group, the waiting and service time for each participant to visit the nurse was obtained from encounter forms completed at each visit. The patient cost of hospitalization was taken as the monetary value of time lost from work.

Only complete data were used to compare results for individual cost items between groups. In the calculation of health system, patient and total costs, averaged values for individual cost items were substituted for missing results. In addition, a sensitivity analysis was performed using extreme rather than average values, as described below.

Effect of Program

The effect of each treatment program was calculated as the average reduction in diastolic BP. Entry BP was calculated by averaging all diastolic BP measurements at the first and second BP screens and the endpoint BP by averaging all diastolic BP measurements at the year-end assessment.

Cost-Effectiveness Analysis

The cost-effectiveness (C/E) of each program was the ratio of the average cost per patient to average reduction in diastolic BP over 1 year. The incremental C/E ratio was obtained by dividing the net increase in medical care cost of the WS program by the net increase in effectiveness. No discounting of future costs and effects was employed because of the short duration of the study.

Sensitivity Analysis

Assessment of the effects of variation in key estimated parameters was carried out by substituting for missing data the maximum cost in the WS group and minimum cost in the RC group. In the WS group, the highest individual drug cost from the group with complete data was used in all patients on medications for whom no data were available. To calculate the total cost for individuals with incomplete drug cost data, the highest monthly cost was substituted for missing monthly data. In the RC group, the least drug cost was substituted for missing data in an analogous manner. The maximum patient cost to visit the physician's office and laboratory in the WS group was calculated by using the longest time (travel, waiting, and service) and the farthest distance when no time-distance data were available and the highest salary category when no wage category was designated. The minimum value for each was used in the RC group whenever data were missing. For patient cost of nursing visits, the highest participant's salary was used whenever salary data were missing. Patients completely lost to follow-up were not included in the sensitivity analysis because they were small in number and evenly distributed between two groups (8% in each group).

Statistics

Means are presented with a standard error of the mean as the index of dispersion. Statistical analysis was carried out using the unpaired two-tail Student's t test, with p value < 0.05 indicating a statistically significant difference. The chi-square statistic was used to assess differences in proportions.

Results

The volunteers who were screened for hypertension represented approximately 50% of the employees offered this service. As shown in figure 1, of the 457 employees, or 2.1% of the initial population screened, were eligible and willing to participate in the study. Selected characteristics of the two study groups are outlined in table 1, and no significant differences were noted. Data on cost and effect were obtained on 214 (92.2%) employees in the WS group and 207 (92.0%)
FIGURE 1. Flow diagram showing results of two-stage blood pressure screening in industry and government, 1977. The percentages in brackets represent the percent of initial population screened.

in the RC group. The other 36 patients had either no cost or effect data and were excluded from further analysis.

Screening Costs

The cost of individual screening items is outlined in table 2. The total screening cost was $102,009; the cost per study participant, $223; and the cost per employee with elevated BP after two BP screenings, $120. Personnel and participants’ costs were the two largest expenses, accounting for 86.1% of the total expense.

TABLE 1. Comparability of Worksite Care (WS) and Regular Care (RC) Participants at Entry by Selected Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>WS</th>
<th>RC</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>232</td>
<td>225</td>
</tr>
<tr>
<td>Age (mean yr)</td>
<td>46.8</td>
<td>46.3</td>
</tr>
<tr>
<td>Systolic BP (mean mm Hg)</td>
<td>152.9</td>
<td>153.9</td>
</tr>
<tr>
<td>Diastolic BP (mean mm Hg)</td>
<td>100.3</td>
<td>100.4</td>
</tr>
<tr>
<td>Male (%)</td>
<td>80.6</td>
<td>76.9</td>
</tr>
<tr>
<td>White (%)</td>
<td>88.0</td>
<td>88.0</td>
</tr>
<tr>
<td>Known hypertension (%)</td>
<td>37.9</td>
<td>38.7</td>
</tr>
<tr>
<td>BP measured in past year (%)</td>
<td>52.6</td>
<td>54.2</td>
</tr>
</tbody>
</table>

BP indicates blood pressure.

Treatment Costs

Health System Cost

Table 3 summarizes the health system cost of care of the two programs. As expected, the mean government insurance expense was higher in the RC group, being $76.03 ± 3.19 compared to $58.17 ± 2.92 in the WS group (p < 0.001). The WS expense included both the cost of laboratory tests ordered by the WS care team as well as the cost of any care for hypertension received from community physicians during the study period. Although 37.5% of WS patients including study dropouts made physician visits, the frequency of their visits was substantially lower (2.9 per annum compared to 5.7 in the RC group; p < 0.001). The mean cost of the nursing service alone was $67.38 ± 1.29. The frequency of visits to the nurse was 8.6 per annum, being significantly higher than the number of physician visits in the RC group (p < 0.001).

There were four admissions to hospital for hypertensive evaluation and management in the RC group, and the mean health system cost was $1,080.71 ± 280.62. No WS patients were admitted to hospital for diagnostic assessment and treatment.

Significantly more WS than RC participants were on drug therapy at some point during the study (205 vs 145, p < 0.001). Moreover, 55.8% of those on drugs in the WS group, compared with 14.9% in the RC group, were on more than one type of antihypertensive medication (p < 0.001). Of those with complete data, the mean drug cost in the WS group was significantly higher ($87.34 ± 7.16 compared to $51.01 ± 5.24 in the RC group, p < 0.001), reflecting the more frequent initiation of efficacious therapy and the more vigorous application of this treatment.

The total health system cost of hypertensive care provided by the WS care team was $197.36 ± 4.99 compared to $129.33 ± 13.34 by community physicians, a difference that was significant (p < 0.001).

Patient Cost

As shown in table 3, the average patient cost for physician visits in the RC group was $65.57 ± 4.84, which was significantly higher than the comparable cost of $38.71 ± 10.54 in the WS group (p < 0.03). The difference was due to more frequent physician visits by RC participants. The average patient cost to visit the laboratory was not significantly different in the two groups, with the WS group cost being $37.40 ± 18.24, and the RC group, $26.67 ± 4.88. The monetary value of the loss of time from work to visit the nurse was $24.09 ± 0.92 per employee and, for the four RC participants to be evaluated in hospital, $372.25 ± 91.65 per patient. The total patient cost was $45.50 ± 3.23 in the WS group and $82.00 ± 6.20 in the RC group (p < 0.01).

Total Cost

Using treatment costs only, we found that the average total cost of the WS program was $242.86 ± 6.94 per participant, which was not significantly
different from the cost of $211.34 ± 18.66 for RC. When screening costs were added to the treatment costs, the difference in cost of medical care between the groups was still not significant.

**Effect**

The mean reduction in diastolic BP, the measure of effectiveness, was 12.1 ± 0.6 mm Hg in the WS group and 6.5 ± 0.6 mm Hg in the RC group (p < 0.001).

**Cost-Effectiveness Analysis**

The C/E ratios of the WS and RC programs using treatment costs only were $20.07 and $32.51 per mm Hg respectively (table 4 and fig. 2). When screening costs were also included, the C/E ratios were higher (WS, $38.50 per mm Hg; RC, $66.82 per mm Hg). The WS program, although more costly by $31.52 per patient per year, was able to achieve an additional mean reduction in diastolic BP of 5.6 mm Hg. Thus, the incremental cost of lowering BP in the WS program, that is, the cost over and above RC, was a $5.63 per mm Hg reduction. Because this is substantially less than the cost of lowering BP in the RC group (at $32.51 per mm Hg reduction), the WS program was highly cost-effective by comparison. If conventional treatment of hypertension (RC) is considered worthwhile, it is clearly more cost-effective to replace RC with WS treatment for the target group identified in this study.

**Assessment of Incomplete Data**

Data for the travel and time part of visits to the physician’s office were complete for significantly more patients in the RC group than in the WS group (50.3% vs 33.3% respectively, p < 0.025). No significant differences in completeness existed for drug cost or the patient cost to visit the laboratory. All other data were available for more than 85% of patients in both groups.
Patients with incomplete data did not differ from patients with complete data in terms of entry BP, year-end BP, change in BP over the study year, or medication compliance.

Sensitivity Analysis

The health system, patient and total costs were recalculated using maximum cost for missing individual items for the WS group and minimum cost for the RC group (table 5). The incremental C/E ratio was still less than the C/E ratio for RC.

Discussion

We have shown that treatment of employed hypertensives at their place of work is both more effective and more cost-effective than usual care in the community.

The C/E ratios for the WS and RC groups were calculated in each case under the assumption that the effect was entirely caused by the treatment program. This supposes that if the two patient groups had not been identified and treated, the group's average BP would be unchanged after 1 year. In the absence of a third "no treatment" control group, this assumption cannot be tested. In the report of the Medical Research Council Working Party on mild-to-moderate hypertension, however, control subjects taking inert tablets or only under observation had approximately a 5 mm Hg fall in their diastolic BP 1 year after entry, which was attributed to familiarity with the measurement procedure and regression toward the mean of the BP in the general population. To test the effect of such a change, we recalculated the C/E ratios after subtracting 5 mm Hg from the effect, and found that patients receiving RC had little BP reduction (table 6 and fig. 2). The WS group, on the other hand, continued to experience a substantial effect beyond the estimated natural reduction in BP.

The health system cost of the WS program was significantly higher than RC. This was related primarily to the use of more medication by the WS care team to control hypertension and the cost of parallel care from community physicians. The latter expense appeared to reflect some initial ambivalence of WS patients to participate in a work-based program without some collaboration from their physician. However, the infrequency of physician visits and the low dropout rate in the WS group suggested good patient acceptance of the medical care provided at the work place.
The major cost saving of the WS program was the reduction in patient cost, while the health system cost of this program was more expensive. Up to this point we have assumed that patient and health system costs are of equal value. It may be argued, however, that the former should be valued at some fraction of the latter. The effect of using different fractions of patient cost in both groups on C/E ratios is illustrated in figure 3. Even if patient cost is completely ignored (fraction of patient cost = 0) and as a consequence the health system cost becomes the total cost, the WS program is still more cost-effective since the C/E ratio for RC, while falling to $19.90 per mm Hg, continues to be higher than the incremental C/E ratio of $12.15 per mm Hg.

While all hypertensive care in the WS program was given on company time, in the RC group visits to the doctor may have been made either on company or leisure time. Because time away from work is not closely monitored in the white collar companies that participated in this study, it was not possible to quantitate this cost. In our cost calculations, equal value was assigned to the time lost from work in the WS group and from work or leisure in the RC group. Since loss of leisure time may not represent a cost to society (no effect on worker productivity), it may be argued that patient cost in the RC group should be valued at some fraction of the patient cost in the WS group. Using different fractions of patient cost for the RC program only, we found that the incremental C/E ratio for the WS program was less than the C/E ratio for RC until the fraction of patient cost was 0.01. We know, however, from the year-end questionnaire that 51.7% of RC patients (roughly equivalent to a fraction of patient cost = 0.52) stated that they took time off work to visit their physician. Moreover, since this time often appeared to be in excess of the actual time required to obtain medical care, the assignment of equal value to patient cost in both groups is not an unreasonable assumption.

Use of the work setting to manage hypertension has many advantages. First it facilitates access to care for a population for whom usual care in the community

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**TABLE 5. Sensitivity Analysis of Worksite (WS) and Regular Care (RC) Programs**

<table>
<thead>
<tr>
<th>Cost</th>
<th>WS</th>
<th>RC</th>
<th>WS-RC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health system cost ($)</td>
<td>$249.44</td>
<td>$130.61</td>
<td>$118.83</td>
</tr>
<tr>
<td>Patient cost ($)</td>
<td>74.81</td>
<td>55.22</td>
<td>19.59</td>
</tr>
<tr>
<td>Total cost ($)</td>
<td>324.24</td>
<td>185.84</td>
<td>138.40</td>
</tr>
<tr>
<td>C/E treatment costs only ($/mm Hg)</td>
<td>26.80</td>
<td>28.59</td>
<td>24.71</td>
</tr>
<tr>
<td>C/E treatment &amp; screening costs ($/mm Hg)</td>
<td>45.23</td>
<td>62.90</td>
<td>24.71</td>
</tr>
</tbody>
</table>

C/E indicates cost-effectiveness.

---

**TABLE 6. Cost-effectiveness Analysis of Worksite (WS) and Regular Care (RC) Programs Assuming 5 mm Hg Reduction in Diastolic Blood Pressure with no Treatment**

<table>
<thead>
<tr>
<th>Cost-effectiveness</th>
<th>WS</th>
<th>RC</th>
<th>WS-RC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment cost ($)</td>
<td>242.86</td>
<td>211.34</td>
<td>31.52</td>
</tr>
<tr>
<td>Effect (mm Hg)*</td>
<td>7.1</td>
<td>1.5</td>
<td>5.6</td>
</tr>
<tr>
<td>Cost-effectiveness ($/mm Hg)</td>
<td>34.21</td>
<td>140.89</td>
<td>5.63</td>
</tr>
</tbody>
</table>

*Subtraction of 5 mm Hg from the observed change in diastolic blood pressure in the WS and RC programs.

---

**FIGURE 3.** Use of fraction of patient cost (FPC) in computing cost-effectiveness (C/E) ratios. The effect on incremental C/E ratio for the worksite care (WS) program is shown under differing assumptions of FPC. While health system and patient costs may be of equal value (FPC = 1), patient cost may also be valued at some fraction of the health system cost. For all FPC values, the incremental C/E ratio (closed circles) is less than the C/E ratio for RC program (closed squares). While equal value was assigned for patient cost in the two groups (FPC = 1), based on different assumptions the patient cost in the RC group may be some fraction of that in the WS group. The incremental C/E ratio for the WS program (open circles) is less than the C/E ratio for RC (closed squares) until the FPC is 0.01.
may be inconvenient. Over a third of the participants at entry were previously aware of having hypertension, and almost one-half had not had a BP measurement for more than 1 year. Second, the population reached at the worksite is primarily middle-aged men in whom the risk of adverse consequences of hypertension is large and the benefit of therapy is more likely to be high. Third, as we have shown here, it is a cost-effective alternative to primary-care practice for the treatment of hypertension. Finally, health care facilities are already available in most places of work with 200 or more employees (in Ontario this is mandatory), which eliminates the need for high capital expense to develop worksite hypertension care programs.

The economic impact of cardiovascular and cerebrovascular disease is enormous, ranking fourth as a cause of sick leave absenteeism among male employees in a heavy industry plant in Ontario. In the same study, the mean work days absent per sick leave episode was much higher for this disease group than for all other diagnostic categories, and vascular deaths accounted for almost half of the total mortality among male employees during the assessment period.

Since hypertension is a major independent risk factor for cardiovascular and cerebrovascular disease in the adult and antihypertensive drug treatment will reduce morbidity and mortality from hypertension, effective industrial hypertension control programs have great potential for improving productivity and/or reducing costs associated with absenteeism or premature death for those employees with asymptomatic, uncontrolled hypertension.

From a policy perspective, decision makers may take into account any or all of the following objectives: 1) to spend the limited resources available for hypertension screening and treatment in a way that will maximize the average BP reduction; 2) to identify and reduce the BP of hypertensive patients by a specified amount as economically as possible; and 3) to maximize the BP reduction per patient. In each instance, the worksite program is more advantageous.

Thus, for the target group identified in this study our findings support health policies that favor allocating resources to work-based hypertension treatment programs.

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