SPECIAL REPORT

National Survey of Exercise Stress Testing Facilities*

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This report surveys the method, volume, protocol, criteria for a positive test, and complications of 518,448 exercise stress tests at 1,375 centers. Exercise test capacity was estimated at 2,147,452. An even distribution of bicycle, Master and treadmill testing was seen by regions within the country. The majority were using the Bruce protocol. The S-T segment depression of .5 mm was considered positive by 4.6 percent; 1.0 mm by 75.4 percent; 1.5 mm by 14.0 percent, and 2.0 mm or greater by 11.9 percent of the centers. Complications were 3.58 infarctions, 4.78 serious arrhythmias, and 0.5 deaths per 10,000 tests. Total of all complications was 8.86 per 10,000 tests. We conclude that exercise stress testing has increased with office-based testing undergoing the greatest expansion. This has been associated with few complications and greater safety.

In 1977, we undertook a survey of exercise stress testing facilities. The purpose was to determine the nature of the laboratories doing testing, how testing was being performed in terms of protocols and methods, and their approximate case loads. We were especially interested in making an estimation of the national capacity to provide stress testing, and also in finding out the type and incidence of complications that were occurring.

METHOD

The marketing research department of two companies producing and selling exercise testing equipment made available their mailing lists of the doctors and institutions doing exercise testing. Questionnaires (Fig 1) were mailed to approximately 6,000 addresses throughout the United States, Canada, and Puerto Rico. Responses were returned from 1,375 centers and analyzed by computer. Following computer analysis, 600 more responses were returned and analyzed separately. These data did not change any of the percentages or ratios. The responses were categorized by region, dividing the country into four parts: West, Midwest, South, and East. The data requested were from the year preceding their receipt of the mailing. The data received represented a center's experience in the 1976 calendar year.

RESULTS

Number of Tests Performed

Those responding reported performing 444,396 treadmills, 44,460 bicycle tests, and 29,592 Master's tests in the calendar year preceding the questionnaire (1976). They estimated their total capacity to be 1,228,120 treadmills, 50,732 bicycles, and 417,600 Master's tests. The total volume of tests reported by this group was 518,448, and they estimated their total capacity to be 2,147,452. The regional volume of testing and capacity was surprisingly similar, although there was a slight tendency to do a higher percentage of treadmill stress tests as compared to bicycle and Master's tests in the Western area (Fig 2).

Volume per Laboratory

There are a few large laboratories doing more than 100 tests per month, but the majority, 70 percent, are doing 50 per month or less as illustrated by Figure 3.

A few years ago, stress testing was a hospital-based procedure, but our findings now show that almost one half of the tests are being done in an office setting. A tendency for this trend predominates in the Western states (Fig 4).

Response by Specialty

A specialty was not designated in 41 percent of the returns. Cardiologists composed 32 percent, internists 6.5 percent, family practitioners 0.2 percent, and 7 percent were nonphysicians. Thirteen percent failed to fall into any of the above classifications, and these included pediatricians, surgeons, and other groups with various interests in this field.
QUESTIONNAIRE - STRESS

NAME: ____________________________

PHYSICIAN: ____________________________

TITLE OF THE RESPONDENT: ____________________________

UNIVERSITY AFFILIATION: ____________________________

2) Address: ____________________________

3) Hospital based
Office based

4) Treadmill
Bicycle
Steps

5) Total stress studies most recent 12 month period
Number treadmill
Number Bicycle Ergometer
Number masters

6) If the demand increased what would be your capacity per year
based on existing resources of equipment, space, and staffing?
A. Bicycle
B. Treadmill

7) Would you be interested in being identified as a center where referrals might be made from appropriate agencies?
Yes
No

8) Parameters monitored during testing:
   a) ECG - Yes
      No
      1. Number of channels 1-2-3-12
      2. Lead groups monitored
      3. Blood pressure
      4. Heart rate
      5. Other
   b) Blood pressure - Yes
      No
      1. Number of channels 1-2-3-12
      2. Lead groups monitored
      3. Blood pressure
      4. Other
   c) Other

9) Parameters monitored during recovery:
   a) ECG - Yes
      No
      1. Number of channels 1-2-3-12
      2. Lead groups monitored
      3. Blood pressure
      4. Other
   b) Blood pressure - Yes
      No
      1. Number of channels 1-2-3-12
      2. Lead groups monitored
      3. Blood pressure
      4. Other
   c) Other

10) Please name protocol if standard:
    a) Continuous
    b) Intermittent
    c) Treadmill
    1. Increased speed and grade
    2. Increased speed and grade constant
    3. Increased grade speed constant

11) Do you require a signed patient consent form?
    Yes
    No

12) Criteria for positive test:
    a) 0.5 mm ST depression
    b) 1.0 mm ST depression
    c) 1.5 mm ST depression
    d) 2.0 mm ST depression
    e) Other

13) Horizontal:
    Down sloping
    Up sloping

14) ST elevation:
    a) 0.05 mm
    b) 1.00 mm

15) Recorded events used for diagnosis:
    a) Chest pain
    Yes
    No
    b) Ventricular arrhythmias
    Yes
    No
    c) Atrial arrhythmias
    Yes
    No
    d) Significant changes in blood pressure
    Yes
    No

16) Do you analyze the ECG by computer?
    Yes
    No

17) Complications:
    a) Number of infarctions (most recent 12 month period)
    b) Number of deaths (most recent 12 month period)
    c) Number of arrhythmias requiring cardioversion
       (most recent 12 month period)

18) Does stress testing include children?
    Yes
    No

19) Does stress testing include isotope imaging?
    Yes
    No

20) Is a physician in continual attendance?
    Yes
    No
    a) If no: Tech
    b) If yes: Does the physician remain more than one at a
    time? (Yes) (Two) (Three) (Number)

21) If computer bank up for compilation and reporting results
    for interpretation were available, would you be interested?
    Yes
    No

22) If Company conducting survey results compiled (check):
    Chest
    Monitor
    EKG

Figure 1. Questionnaire on stress testing.

Protocol and Methods of Testing

The majority of people doing treadmill stress testing are using the Bruce protocol (65.5 percent).
It should be pointed out that the nature of this mailing list has probably biased the data in favor of bicycle and treadmill stress testing. The true incidence of the Master's step test is not indicated from these data. There was a striking similarity in the distribution of protocols used in each region. Blood pressures were not recorded during the test at 3 percent of the facilities. A written consent was obtained prior to exercise at 82 percent of the centers reporting. A surprise finding was that 12 percent of the centers described stress testing without ECG monitoring.

Analysis of S-T Changes and Leads Utilized

The S-T segment depression considered to be positive for ischemia was reported as follows: S-T depression of 0.5 mm was the standard at 46.6 percent; 1.0 mm at 75.4 percent; 1.5 mm at 14.0 percent; and 2.0 mm or greater at 11.9 percent of the centers. The S-T elevation of 1.0 mm was considered positive at 46.6 percent, while 31 percent required 2 mm of S-T elevation. In analysis of the configuration of S-T segment change, 85.1 percent required that the S-T segment be horizontal, 72 percent accepted downsloping as abnormal, and only 12.6 percent considered an upsloping pattern as a positive test.

Complications

The complications reported during the most recent 12 months are tabulated in Figure 5. There were 74 centers (5.4 percent) reporting one infarction; 27 (2 percent) reporting two to five infarctions; and four centers (0.3 percent) who reported six or more infarctions per year. A total of 3.58 infarctions per 10,000 tests is estimated. Arrhythmias requiring special treatment such as cardioversion or intravenous medication occurred in 95 centers (6.9 percent), 28 (2 percent) reported two to five cases of this type of arrhythmia, and ten centers (0.7 percent) reported six or more of these arrhythmias. This calculates to 4.78 serious arrhythmias per 10,000 tests. One death (1976) was reported by 16 (1.2 percent) of the centers, and one center (0.1 percent) reported two to five deaths. NOTE: this particular center was office-based. One center reported six or more deaths. NOTE: this was a hospital-based center. This represents 0.5 deaths per 10,000 tests. The total of all three major complications was 8.86 per 10,000 tests.

Discussion

It would be interesting to know how many stress tests are done annually in the United States. There is no way to accurately ascertain this information from our data; however, we have reached less than one-half of all the laboratories and physicians engaged in stress testing. If this is correct, there were
at least 1 million tests done in 1976, and there must be many more done annually in 1978. This would place the estimated capacity at well over 2 million tests per year, and might possibly be 3 million. The trend to do testing in the office setting is increasing rapidly, so that there may be fewer centers doing a very large volume in the future. As the procedure becomes more popular in our own community, we have seen the volume in our own laboratory decrease.

**Specialty**

For some reason, 41 percent of our respondents failed to identify their specialty. We would suppose that only a few of these were cardiologists, so that it would appear that more than one-half of the tests are done by practitioners outside this subspecialty. We know from personal contacts that many physicians in family medicine and internal medicine are involved in stress testing. There is also increasing interest among pediatricians and in certain non-medical facilities such as the Department of Physical Education and health clubs.

**Methods**

In 1971, Rochmis and Blackburn reported that 60 percent of their respondents were using a treadmill; our study shows an increase to approximately 78 percent. In their study, 45 percent were using the Master steps, and our 10 percent to 12 percent reported using this method. The incidence of the devotees to the bicycle has not changed substantially. We believe that our questionnaire probably underestimates the use of the Master's test because our mailing list would favor a distribution toward treadmill and bicycle testing. This type of bias was probably also present in the previous study. The protocol most popular is that developed by Bruce, which is a progressive continuous treadmill protocol where the grade and speed are increased every three minutes. Bruce advocates a symptom-limited maximum work load. Although we failed to specifically ask for information relating to the use of a maximal stress test, it can be assumed from the protocols reported that about 70 percent are using at least a symptom-limited maximum procedure.
S-T Changes and Lead Systems

Approximately 75 percent of the respondents have accepted the concept that 1 mm of horizontal or downsloping S-T depression indicates ischemia. A few are still using 1.5 to 2 mm. In spite of a number of recent papers to the contrary, the upsloping pattern is still viewed with considerable skepticism. There is a significant trend toward multichannel recording with 30 percent using 3, and 23 percent using 12 leads. This undoubtedly has been influenced by the availability of several excellent multichannel recording systems now on the market.

Safety

One of the most significant findings reported by Rochmis and Blackburn was the complication rate.

Complications: (most recent 12 month period)

<table>
<thead>
<tr>
<th>Infarctions</th>
<th>5.4% (74)</th>
<th>2-5</th>
<th>2.0% (27)</th>
<th>6+</th>
<th>3.3% (4) Hosp Based (2)</th>
</tr>
</thead>
</table>

<table>
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<tr>
<th>Deaths (centers)</th>
<th>1.2% (16)</th>
<th>2-5</th>
<th>0.1% (1) Office Based</th>
<th>6+</th>
<th>0.1% (1) Hospital Based</th>
</tr>
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</table>

Estimated 0.5 Deaths per 10,000 Tests

Arrhythmia (centers)

<table>
<thead>
<tr>
<th>Type</th>
<th>6.9% (93)</th>
<th>2-5</th>
<th>2.0% (28)</th>
<th>6+</th>
<th>0.7% (10)</th>
</tr>
</thead>
</table>

Estimated 4.78 Arrhythmias per 10,000 Tests

Estimated total complications 8.86 per 10,000 Tests

The mortality figure of one per 10,000 has often been quoted and has been accepted as the risk inherent in stress testing. It would seem safe to conclude that this risk has been cut in half and now stands at 0.5 deaths per 10,000. This may be due to a better understanding of the contraindications to testing, and an improvement in our understanding of the physiology of exercise. For a long time, it was believed that a submaximal test (target heart rate) was safer than one where subjects were pushed to a point near their maximal capacity. Rochmis and Blackburn's survey found that only 34 percent of their respondents used maximal tests. Our study showed 70 percent are using a symptom-limited maximum test, with a reduction in mortality. In their listing of the 16 reported deaths, ten were tested only at low levels, and only two of the four who completed maximal tests could actually be classified as a stress test complication. This would suggest that testing people at a submaximal level does not add any particular margin of safety.

There were 3.5 infarctions per 10,000 tests and 4.8 serious arrhythmias. These figures cannot be compared exactly to those of the previous survey because of a different method of reporting. It would appear, however, that in spite of the widespread use of exercise stress testing at locations away from hospitals and medical centers, the risk is certainly no more, and probably less than it was in 1970. We would hope this trend would continue as the method continues to increase in acceptance.

In summary, there has been a large increase in stress testing throughout the United States that has evolved from a hospital-based procedure to one that is used by many physicians as part of their office evaluation of patients. The methodology indicates a more sophisticated approach to the procedure with better equipment and a better understanding of exercise physiology. These trends have been associated with an increase in safety in spite of the increase in volume and the diversity of the physicians involved in this procedure.

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REFERENCES