An assessment of the cost-effectiveness of fast tracking bacteriological specimens for mycobacteria

Marta Baboresa, Pat Morrellb, Dee Edenb, P. Daviessc,*

aMacclesfield District General Hospital, Macclesfield, SK10 3BL, UK
bHealth Protection Agency, University Hospital Aintree, Liverpool, L9 7AL, UK
cTuberculosis Research and Resource Unit, Cardiothoracic Centre, Thomas Drive, Liverpool, L14 3PE, UK

Received 12 September 2003; accepted 6 February 2004

Summary A virtual model, using six predetermined criteria for fast tracking tuberculosis specimens was devised to improve the cost effectiveness of the MB/BacT system. All specimens received at a central laboratory were audited for the six criteria over a 6-month period. By assuming that only those specimens fulfilling these criteria were fast tracked the theoretical cost savings could be calculated. To prevent possible delay in speciating mycobacteria, the number of criteria were expanded to nine, and a further 6 month audit carried out.

In the first 6-month period, 728 specimens were tested. Had the initial hypothetical criteria excluded some of the specimens, only 351 specimens would have been tested through the fast-track system at a saving of $942 (52%) of the total cost, but five culture results positive for environmental mycobacteria would have been delayed. In a second 6-month survey the criteria were expanded. Using these no positive culture would have been missed but the savings would only have been 26% of the total cost.

Introducing exclusion criteria for rapid testing can improve the cost effectiveness of rapid culture methods with no important loss of clinically necessary information.

© 2004 Elsevier Ltd. All rights reserved.

Introduction

Anyone working in medicine is aware of the need for cost savings and of obtaining value for money.1 A trawl of literature seeking cost effective use of resources in tuberculosis control revealed 114 references published in peer reviewed journals since 1976. Relatively few papers were concerned with cost effectiveness or cost savings of diagnostic methods.2–8 In developed countries, a very high proportion of specimens tested for tuberculosis are likely to be negative.

Though providing more rapid identification of the tuberculosis organism, the liquid MB/BacT culture system is more expensive than conventional techniques using solid Lowenstein–Jensen media. We have therefore devised a virtual model based on pre-determined criteria to examine the cost effectiveness of excluding certain specimens from the fast culture (MB/BacT system). We have, by this method, established specific criteria for fast tracking specimens using MB/BacT, which we believe, provides the most cost-effective way of using the system.

KEYWORDS
Tuberculosis; Fast tracking; Cost-effectiveness; Clinical criteria; Mycobacteria

0954-6111/$ - see front matter © 2004 Elsevier Ltd. All rights reserved.
doi:10.1016/j.rmed.2004.02.009
Methods

In the laboratory carrying out the audit all specimens are routinely cultured on sold Lowenstein–Jensen medium as well as (MB/BacT).

In the MB/BacT system culture takes place in a process bottle containing modified Middlebrook 7H9-broth medium supplemented with growth factors. Bottles are inoculated with either sterile production of CO2 in monitored continuously by an infrared detection system.

Production of CO2 changes the color of a gas permeable sensor in the base of the bottle. The lighter color results in an increase of reflectance units, which are being monitored and recorded by the instrument every 10 min. Readings are analyzed by computer driven algorithms and once a pre-set threshold has been reached, an audible signal alerts the operator that a bottle should be entered and further examined.

Confirmation of the presence of acid-fast bacilli (AFB) is made by Stain.

Detection of positive MB/BacT cultures has on average been found to be more sensitive and twice as rapid as by conventional cultures on solid media.9–11

We first audited all respiratory specimens prospectively, which arrived at the laboratory for testing for mycobacteria during a 6-month period. We set up hypothetical criteria to see how many positive results would have been delayed if only the specimens following the criteria had been put through the fast-track system.

The criteria were as follows:

(1) At least one of the following mentioned on the laboratory form
   A. A previous history or contact with TB.
   B. TB queried on laboratory form.
   C. Haemoptysis.
   D. Weight loss.
   E. Night sweats.
   F. Living abroad or recent travel history.
(2) All the specimens from a children’s hospital.
(3) All AFB smear positive specimens.

We then added 3 more criteria for a second 6-month period of audit, to see if this could improve the completeness of information without reducing cost-effectiveness. In this second audit the criteria for selection was as above plus the following information:

(1) Patients with HIV +ve serology.
(2) Shadowing on chest-X-ray
(3) All bronchial washings from non-ITU patients.

The cost of the MB/BacT bottles is given as £2.50 ($4.50). A conversion rate of $1.80 to £1 has been used throughout. Only information available on the microbiology request form was used. No further clinical information was sought. Specimens from extra-pulmonary sites were not included in the audits as, by the laboratory’s experience, positive findings were likely to be very rare.

Results

Laboratory test specimens for which smear and culture for TB were requested came from eight hospitals in the region, which were three teaching hospitals, four District general hospitals, and a children's hospitals.

During the first 6 months of the study our laboratory received 728 respiratory specimens requesting testing for AFB of which 571 were sputa and 157 bronchial washings.

Of the 571 sputum specimens information given on 308 (54%) of these fulfilled the criteria.

Of the original 571 sputum specimens 27(4.4%) had a positive culture result, 22 from specimens which would have fulfilled the criteria for fast track and five which did not.

These five specimens, all of which were smear negative, grew environmental Mycobacteria not M. tuberculosis, which were; M. avium intracellulare (3) and M. terrae (2) from four different patients (Table 1).

In addition to the 571 sputum specimens, 157 bronchial washing specimens were tested for Mycobacteria of which 43 specimens (26%) fulfilled the criteria.

Only five out of 147 (3%) bronchial washing specimens were subsequently culture positive for M. tuberculosis.

If these criteria had been used to exclude some specimens, which would not therefore have been passed through the fast-track system, the use of 263 bottles at a cost of £657.50 ($1184) would have been avoided. Only 43 (28%) bronchial washing specimens fulfilled the criteria. Excluding the rest would have saved 114 bottles at a cost of £285 ($513).

The total saving in the 6-month period would therefore have been £942 ($1696) or 52.5% of the actual cost of £1795 ($3231) for fast tracking all the 728 specimens.

As the initial set of criteria would have excluded five culture positive specimens, and in order to improve the pick up rate we added three more criteria, stated on the laboratory form in a second 6 month prospective audit period. (See above).
During this second period we audited all the specimens from just one hospital: the one with the largest caseload.

A total of 325 sputum specimens and 98 bronchial washings were tested during the second 6 months period of which 236 (73%) sputum specimens and 83 (85%) bronchial washings fulfilled the criteria for fast tracking.

Following these new criteria would have resulted in a total of 89 bottles saved for sputum and 15 bottles saved for bronchial washings specimens at a total cost of £260 ($468). The actual cost of fast tracking all 417 specimens was £1042.50 ($1182). Thus using the expanded set of criteria could have made a saving of 25% of the costs. No positive specimens would have been delayed in the second audit (Table 2).

Comparing the two audits, the savings were lower but still considerable in the second audit.

**Discussion**

We have shown that using sets of criteria, based on information provided on the laboratory form, to decide whether to fast-track specimens for bacteriological culture, can provide considerable cost savings. The first audit using a relatively restricted set of criteria would have saved approximately 50% of the costs of the MB/BacT system. Had these been used the results for four patients with smear negative culture positive isolates for environmental mycobacteria (sometimes called mycobacteria

### Table 1 Mycobacterial species by smear and culture result for the two periods of audit.

<table>
<thead>
<tr>
<th>Isolate</th>
<th>Smear+ Culture+</th>
<th>Smear+ Culture-</th>
<th>Smear- Culture+</th>
<th>Smear- Culture-</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sputum</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>M. tuberculosis</em></td>
<td>8</td>
<td>1</td>
<td>5</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td><em>M. avium</em></td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td><em>M. kansasii</em></td>
<td>4</td>
<td></td>
<td>1</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td><em>M. chelonae</em></td>
<td>1</td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><em>M. gordonae</em></td>
<td>2</td>
<td></td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td><em>M. terrae</em></td>
<td>2</td>
<td></td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td><em>M. malmoense</em></td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>10</td>
<td>9</td>
<td>5</td>
<td>32</td>
</tr>
<tr>
<td><strong>Bronchial washing</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>M. tuberculosis</em></td>
<td>11</td>
<td>4</td>
<td>5</td>
<td>1</td>
<td>21</td>
</tr>
<tr>
<td><em>M. avium</em></td>
<td>5</td>
<td>8</td>
<td>1</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td><em>M. kansasii</em></td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td><em>M. chelonae</em></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td><em>M. gordonae</em></td>
<td>9</td>
<td></td>
<td></td>
<td>9</td>
<td></td>
</tr>
<tr>
<td><em>M. terrae</em></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><em>M. malmoense</em></td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>19</td>
<td>26</td>
<td>9</td>
<td>5</td>
<td>59</td>
</tr>
</tbody>
</table>

### Table 2 Cost savings for the two audits.

<table>
<thead>
<tr>
<th>Audit 1.</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total specimens sent to lab.</td>
<td>728</td>
<td>Cost of MB/BacT</td>
<td>£1820 ($3276)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specimens fulfilling criteria</td>
<td>351</td>
<td>£877.50 ($1580)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specimens not fulfilling criteria</td>
<td>377</td>
<td>£942.50 ($1697) (52% of total)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Audit 2.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total specimens sent to lab.</td>
<td>417</td>
<td>Cost of MB/BacT</td>
<td>£1042.50 ($1877)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specimens fulfilling criteria</td>
<td>315</td>
<td>£787.50 ($1418)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specimens not fulfilling criteria</td>
<td>98</td>
<td>£245 ($441) (24% of total)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
other than tuberculosis, non-tuberculous mycobacteria, atypical or opportunist mycobacteria) would have been delayed. The clinical importance of this is uncertain but unlikely to be significant.

Thus we would recommend the more restricted criteria saving about 50% of costs be used. The capital cost of the system has not been entered into the calculations, as this would be the same whether some or all of the specimens were passed through.

Many laboratories are now considering the use of polymerase chain reaction (PCR) techniques to speed the speciation of mycobacteria. These are still being evaluated but unlike the MB/BacT system, PCR has a lower sensitivity and specificity for mycobacteria than solid and liquid media methods. Its main value is in the detection of environmental mycobacteria in the presence of a positive smear.

The expense probably precludes their use in developing countries where the relatively modest cost of the BacT system may be more easily affordable. An analysis similar to our study of the way cost effectiveness of the more expensive MB/BacT system could be used also applies to a PCR-based rapid species identification system.

With increased awareness of tuberculosis there is likely to be increasing demand for bacteriological tests for AFB. In this study only 4.4% of tests produced a positive culture. Some ability to reduce costs by excluding tests unlikely to be positive from the expensive fast-track system would be an advantage.

We have shown that blanket use of more rapid and more expensive techniques of species (and sensitivity) identification can be avoided with no loss of clinically useful information in a setting of a public health system in a Western European City. It is probable that other centres can do the same but the exact criteria they should use for specimen selection may have to be determined locally.

Acknowledgements

We would like to thank Dr. Ian Farrell, Director of the Health Protection Agency, Liverpool for help with the project.

References