A national audit of performance standards for blood cultures in Aotearoa New Zealand: opportunities for improvement

Juliet Elvy, Michael Addidle, Hanna-Sofia Andersson, Vivian Black, Dragana Drinković, Julia Howard, Michael O'Connor, Susan Taylor, Arthur J Morris

ABSTRACT

AIMS: To audit key quality indicators for blood culture (BC) practices across Aotearoa New Zealand to facilitate national BC practice peer review and promote BC quality improvement interventions.

METHOD: Microbiology laboratories providing diagnostic services to district health board (DHB) hospitals were invited to participate. Practice was compared against published BC recommendations. Laboratories were required to submit data for BC positivity and contamination rates, BC bottle fill volume and the proportion of BC received as a single set.

RESULTS: Laboratories serving 15 of the 20 DHBs participated in the audit. Nine DHBs (60%) demonstrated a positivity rate within the target range of 8% to 15%. Eight DHBs (53%) reported a contamination rate lower than the accepted 3%, but seven (47%) DHBs exceeded this target and two reported a contamination rate greater than 5%. Mean BC bottle fill volumes were generally greater than the target of 8mL, but this volume was not reached by three DHBs and a further three were unable to provide fill volume data. No DHB met the audit standard for single-set BCs representing <20%, and for six DHBs single-set BC comprised more than half of all samples. No DHB failed all audit targets.

CONCLUSION: This audit demonstrates wide variation in BC performance across New Zealand. In most instances an inadequate volume of blood is being collected, lowering the chance of culturing a pathogen. A significant opportunity for improvement exists; clinical services and laboratories are encouraged to work together to implement targeted quality improvement processes to correct deficiencies in practice.

Blood cultures (BC) are among the most important samples processed in the clinical microbiology laboratory. They remain the gold standard investigation for bloodstream infections, and an essential diagnostic tool for severe infections such as infective endocarditis, bone and joint infections and meningitis.[1] Optimising BC practices can improve pathogen recovery and optimise infection management with targeted antimicrobial therapy, improved patient outcomes and support of antimicrobial stewardship efforts.[2–4]

Many factors influence BC quality, including BC collection technique, BC bottle volume of fill, and the number of BC bottles obtained. While there are several published BC best practice guidelines,[5–9] national compliance with such performance criteria has never been reported and many of these key steps are not measured.[10] We therefore sought to audit the key quality indicators for district health board (DHB) BC practices across microbiology laboratories around the country. The overall purpose of the study was to facilitate national peer review of BC practices, provide benchmarking and promote quality improvement interventions. This was an initiative undertaken, and supported, by the New Zealand Microbiology Network (NZMN), a national group consisting of clinical microbiologists, representatives from the Ministries of Health and Primary Industries, Medical Officers of Health and the Institute of Environmental Science and Research (ESR).

Method

This audit was carried out before the transition to the new health system Te Whatu Ora – Health New Zealand. Microbiology laboratories providing diagnostic services to DHB hospitals were all invited to take part. Participating laboratories were required to interrogate their own laboratory information systems pertaining to adult BC practices (age ≥18 years) to provide audit data for

the period 1 July to 31 July 2021. Paediatric blood cultures were excluded.

Data required were:

1. The total number of BC sets submitted to the laboratory during the month of July 2021.
2. The number and proportion of BC sets that yielded a pathogen.
3. The number and proportion of BC sets that yielded a contaminant.
4. The mean BC bottle fill volume (in mL) and the number and proportion of bottles received with less than 50% of the recommended fill volume.
5. The number and proportion of BCs received as a single set (consisting of just one aerobic and one aerobic bottle).

A pathogen was defined as *Staphylococcus aureus*, *Streptococcus pneumoniae*, beta-haemolytic streptococci, *Listeria monocytogenes*, *Escherichia coli* and other members of the *Enterobacterales*, *Pseudomonas aeruginosa*, *Neisseria meningitidis*, *Haemophilus influenzae*, anaerobic Gram-negative bacteria (such as *Bacteroides* species and *Fusobacterium* species) and *Candida* species, or where the clinical microbiologist or treating physician deemed the cultured organism to be clinically significant.

A contaminant was defined as a single blood culture positive for coagulase-negative staphylococci, *Corynebacterium* species, *Micrococcus* species, *Cutibacterium acnes*, *Bacillus* species (not *B. anthracis*), alpha-haemolytic streptococci or where the clinical microbiologist or treating physician deemed the cultured organism to be a contaminant. Where an organism commonly considered to be a contaminant was present in more than one set, the responsible microbiologist categorised the isolate as either a pathogen or contaminant after clinical review.

BC bottle fill volumes were required to be measured for a minimum of 7 days during the audit period. Where fill volume was measured manually, participating laboratories determined this by weighing each bottle and comparing it to the average weight of an empty (unfilled) bottle as follows: (weight of bottle in grams – average weight of empty bottle in grams)/1.06.

Laboratories with automated capability for fill volume measurement, for example by using the BacT/ALERT Virtuo (Biomérieux) or BacTec EpiCenter/Synapsys (Becton Dickinson) automated systems, reported fill volumes utilising this method.

All data was reported to, and collated by, the first author on behalf of the NZMN and assessed for compliance with the following audit standards:[5–9]

1. Proportion of BC positive for a pathogen, or positivity rate, 8 to 15%.
2. BC contamination rate less than 3%.
3. Mean BC bottle fill volume 8 to 10mL.
4. Less than 20% of bottles with a fill volume of less than 4mL.
5. Less than 20% of BC series as a single set.

Laboratories were also asked to provide, where possible, data for two additional quality measures:

1. The average time taken for BC bottles to reach the laboratory after collection.
2. The average time from receipt in the laboratory to loading onto the BC analyser.

Results

The performance of the 15 participating DHBs across Aotearoa New Zealand against the five audit standards is presented in Table 1. Nine DHBs (60%) demonstrated a positivity rate within the target range of 8% to 15%. Eight DHBs (53%) reported a contamination rate lower than the accepted target of 3% but seven DHBs (47%) exceeded this target and two reported a contamination rate greater than 5%. Mean BC bottle fill volumes were generally greater than 8mL, but this target was not reached by three DHBs (20%) and a further three were unable to provide any fill volume data. Approximately 12% of sets contained <4mL of blood per bottle (Table 1). Where fill volume data was able to be reported, all DHBs met the target for less than 20% with a fill volume lower than 4mL. Conversely, no DHB met the audit standard for single-set BCs comprising less than 20% of samples, and for six DHBs single-set BC comprised more than half of all samples. Overall, 5,398 (44%) of 12,306 sets were single sets. No DHB failed to meet all audit targets.

Voluntary additional data pertaining to time from BC collection to receipt in the laboratory, and time from receipt to incubation, were provided by only a minority of laboratories (n=5). Furthermore, the accuracy of this data, where reported, was questionable, e.g., implausibly long delays were reported for some individual BC samples. This data has therefore been excluded from analysis.

Table 1: Audit results for participating DHBs for each of the quality measures.

District health board	Number of BC sets	Positivity rate, % (n)	Contamination rate, % (n)	Mean fill volume in mL	% with fill volume <4mL	Single set BC, % (n)
Bay of Plenty	1,121	11.0 (123)	1.7 (19)	**7.9**	11.8*	**46.5 (521)**
Capital and Coast	1,595	8.7 (138)	2.0 (32)	9.5	14.8*	**59.4 (947)**
Canterbury	1,920	**6.4 (123)**	1.8 (34)	8	15–20*	**37.5 (720)**
Counties Manukau	1,917	10.5 (201)	2.3 (45)	Not provided	Not provided	**37.8 (725)**
Hutt Valley	508	**6.9 (35)**	**3.9 (20)**	10.2	4	**76.2 (387)**
Lakes	444	13.1 (58)	2.3 (10)	Not provided	Not provided	**35.8 (159)**
MidCentral	372	**7.5 (28)**	**6.2 (23)**	8.5#	14.8#	**60.0 (315/526)**
Nelson Marlborough	397	11.3 (45)	**3.8 (15)**	9.1	10.2	**36.2 (144)**
South Canterbury	154	**15.6 (24)**	**4.5 (7)**	8.4	18.8	**25.3 (39)**
Southern	1,101	9.6 (106)	2.6 (29)	8.3	8*	**48.7 (537)**
Tairāwhiti	215	12.0 (26)	**3.7 (8)**	Not provided	Not provided	**56.0 (120)**
Taranaki	413	8.3 (34)	**4.4 (18)**	**7.5**	18.8	**66.2 (274)**
Wairarapa	245	**5.3 (13)**	2.4 (6)	**7.8**	34	**44.1 (108)**
Waitematā	1,771	**5.6 (99)**	1.0 (17)	10	5.6	**22.0 (389)**
Whanganui	133	12.0 (16)	**6.0 (8)**	8.5#	14.8#	**78.0 (137/176)**
Target audit standard	**-**	**8–15%**	**<3%**	**≥8mL**	**<20%**	**<20%**

Red shading denotes audit target not met.
*Data obtained by automated method.
#MidCentral and Whanganui DHBs fill volumes are presented as a combined value by a single laboratory provider.

Discussion

The importance of BCs cannot be underestimated as they remain the gold standard diagnostic tool for sepsis and severe infections, such as infective endocarditis and meningitis. Optimal management relies on an accurate and timely microbiological diagnosis, but this is achieved in only 30–40% of sepsis cases.[2–4] Accordingly, microbiology laboratories, together with frontline clinical services, have an important role to play in efforts to optimise BC sampling.

There are a number of well-established BC consensus guidelines which outline the recommended BC practices and quality standards.[5–9] However, there is no mandatory requirement to comply with these standards, and this audit demonstrates that there is wide variation in BC performance across most of the parameters measured.

Five DHBs demonstrated a positivity rate below 8%. A low positivity rate may reflect lower test sensitivity due to inadequate sample volumes or an over-representation of BC from patients with a low pre-test probability of bacteraemia. Conversely, too high a positivity rate may reflect too few BC being performed and bacteraemias going undetected. DHBs are encouraged to review their current practice to avoid performing BC for low-yield conditions such as mild cellulitis, non-severe pneumonia, cystitis or transient post-operative fever. Targeting patient selection to conditions with a high (e.g., sepsis, endovascular infections, septic arthritis, meningitis) or moderate (e.g., severe cellulitis, severe community-acquired pneumonia, cholangitis) likelihood of infection is recommended.[1]

Seven DHBs demonstrated a contamination rate greater than 3%, with two DHBs exceeding 5%. BC contamination is common, and to some extent unavoidable, but potentially leads to unnecessary use of antibiotics, increased length of stay, unwarranted investigations and missed diagnosis.[11–15] The true impact of BC contamination at a given institution will depend on a variety of local factors,[16] but it is discouraging that seven DHBs did not meet the audit target for this parameter. Setting a target rate, introducing BC collection bundles, using sample diversion devices, ongoing education and feedback have all been shown to progressively lower contamination rates over time.[17–22] Arguably, a contamination rate target of less than 1% may be more clinically appropriate[23] but BC practices in New Zealand would require further quality improvements to achieve this. BC collection by phlebotomists has consistently been shown to reduce the risk of contamination[24] but this is not usually available nor is it routine practice for BC in most centres.

Under-filling of individual BC bottles was not a common problem in this audit, with most DHBs compliant with a mean fill volume of more than the recommended 8mL. However, three participant sites were not able to provide fill volume information for the given audit period. In a recent survey of Australasian laboratories, only two out of 93 laboratories (2%) indicated that they regularly monitored the BC volume of fill,[10] despite all BC standards recommending this be done.[5–9] While this audit didn't explore the barriers to fill volume measurement, such data often relies on manual inspection or weighing of bottles, which is time consuming and laborious. Newer BC analysers include automated functionality for fill-volume measurement (for example, using photometric technology)[25–28] but this capability is not yet available for many laboratories that rely on older analysers until upgrades or replacements are due.

All DHBs missed the target for single-set BC draws, which compromises test sensitivity [29–32] and can make accurate interpretation of positive cultures more challenging. Adequate blood volume has repeatedly been shown to be the single most important factor affecting BC sensitivity because there is usually a very low concentration of circulating micro-organisms. Accordingly, the likelihood of pathogen recovery is directly proportional to the volume of blood collected.[29–32] For this data set only 50% of collects were ≥16mL where 40mL–60mL was recommended. This implies an approximately 25%–45% lower yield for these BCs than expected with the recommended blood volume. If a pathogen is not detected because it was not included in the sample, possible clues to the origin of infection may be missed along with the ability to rationalise patient treatment based on susceptibility results.

Blood volume is a function of both the individual bottle fill volume and the number of BC bottles obtained; laboratory standards and sepsis guidelines all recommend collection of 2 to 4 sets, 8–10 mL per bottle, before starting antimicrobials.[2,3,5–9] Even with modern BC analysers, the test sensitivity expected from 20mL, 40mL, and 60mL BC collects is 65%–75%, 80%–90%, and 96%–98% respectively, i.e., approximately 1% increase in pathogen yield per mL of blood cultured.[29–32] Hence, performing single-set draws (consisting of just one aerobic and one anaerobic bottle) or

under-filling BC bottles significantly reduces test sensitivity and limits the chance of identifying the pathogen. While it is disappointing to find single-set draws being commonly performed in the majority of DHB hospitals, this could be addressed with regular education, monitoring and feedback to frontline clinical and phlebotomy teams to emphasise the importance of optimising sample volume, which has been shown to be highly effective to improve practice in this regard.[33,34] This audit did not explore the barriers to obtaining more BC sets, but the traditional requirement for separate venepunctures is a major inconvenience and is likely to have an impact. More recent evidence suggests that obtaining multiple BC sets via a single venepuncture can successfully reduce the proportion of single sets while also reducing contamination, and this approach should be considered.[35,36]

Very few laboratories in our audit were able to provide the additional voluntary data regarding timings from BC collection to arrival into the laboratory and onward loading on to the BC analyser. These variables were therefore not able to be reported. Delays in BC loading can prolong the turnaround time and BC standards recommend loading within 2 to 4 hours of collection.[5–7] Lack of access to accurate data of this sort is commonplace but problematic, and resolution of this issue would require changes to laboratory information systems.

There are several limitations to our study. Not every DHB was able to participate, and we did not explore the reasons why some DHBs failed to meet certain BC quality standards. An audit period of 1 month is a short snapshot period and may not provide an accurate reflection of practices. This may disadvantage smaller DHBs with fewer numbers of BC samples where a single contaminant will skew results to a greater extent than for larger DHBs performing more BC. We excluded paediatric BC in recognition of the difficulties faced for paediatric sample collection and the lack of consensus for the required fill volumes. However, BC optimisation is as relevant for children as it is for adults, since contamination rates may be high, sample volumes low and overall fewer BC bottles per patient episode;[37,38] it is therefore advisable for services to include paediatric samples in BC quality improvement activities wherever possible.

We did not ask whether laboratories had already in place any regular audit feedback cycle for BC quality measures. Improvements in pre-analytical processes, such as sampling technique and patient selection, are outside the direct control of the laboratory, require ongoing training, education, audit and feedback to clinical teams,[5–9] and can be difficult and time-consuming to maintain. While the laboratory is well placed to drive improvement in BC standards, clinical services must also play their part. The NZMN recommends that regular monitoring and feedback processes be implemented to review ongoing performance.

To conclude, this audit demonstrates a wide variation in BC performance across New Zealand and has identified many opportunities for improvement. Laboratories, hospitals and Te Whatu Ora – Health New Zealand are encouraged to work together to review and implement targeted BC quality improvement processes where deficiencies in practice exist. Laboratory and hospital accreditation agencies would do well to ensure BC quality assurance activity is implemented and regularly reviewed. Such improvements would aim to optimise management of patients with bloodstream infections, which disproportionately affects Māori and those of lower socio-economic status.[39] Ultimately improved BC quality performance will help improve antimicrobial stewardship efforts and will be of direct benefit to patients and their whānau.

COMPETING INTERESTS
Nil.

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AUTHOR INFORMATION
Juliet Elvy: Microbiology Department, Southern Community Laboratories, Dunedin and The New Zealand Microbiology Network.
Michael Addidle: The New Zealand Microbiology Network and the Microbiology Department, Pathlab, Tauranga.
Hanna-Sofia Andersson: The New Zealand Microbiology Network and the Microbiology Department, Medlab Central (Palmerston North and Whanganui Hospitals) and TLab (Gisborne Hospital), Palmerston North.
Vivian Black: Microbiology Department, Southern Community Laboratories, Dunedin and The New Zealand Microbiology Network.
Dragana Drinković: The New Zealand Microbiology Network and the Microbiology Department, North Shore Hospital, Auckland.
Julia Howard: The New Zealand Microbiology Network and the Microbiology Department, Canterbury Health Laboratories, Christchurch Hospital, Christchurch.
Michael O'Connor: Microbiology Department, Wellington Southern Community Laboratories, Wellington.
Susan Taylor: The New Zealand Microbiology Network, and the Microbiology Department, Middlemore Hospital, Otahuhu.
Arthur J Morris: Microbiology Laboratory, LabPLUS, Auckland City Hospital, Auckland.

CORRESPONDING AUTHOR
Juliet Elvy: Microbiology Department, Southern Community Laboratories, Dunedin Hospital, 201 Great King Street, Dunedin, 9016. Ph: 0278393726. E: Juliet.elvy@sclabs.co.nz

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