BMJ Open   Incidence of ventilator-associated pneumonia in Australasian intensive care units: use of a consensus-developed clinical surveillance checklist in a multisite prospective audit

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ABSTRACT

Objectives: With disagreements on diagnostic criteria for ventilator-associated pneumonia (VAP) hampering efforts to monitor incidence and implement preventative strategies, the study objectives were to develop a checklist for clinical surveillance of VAP, and conduct an audit in Australian/New Zealand intensive care units (ICUs) using the checklist.

Setting: Online survey software was used for checklist development. The prospective audit using the checklist was conducted in 10 ICUs in Australia and New Zealand.

Participants: Checklist development was conducted with members of a bi-national professional society for critical care physicians using a modified Delphi technique and survey. A 30-day audit of adult patients mechanically ventilated for >72 h.

Primary and secondary outcome measures: Presence of items on the screening checklist; physician diagnosis of VAP, clinical characteristics, investigations, treatments and patient outcome.

Results: A VAP checklist was developed with five items: decreasing gas exchange, sputum changes, chest X-ray infiltrates, inflammatory response, microbial growth. Of the 169 participants, 17% (n=29) demonstrated characteristics of VAP using the checklist. A similar proportion had an independent physician diagnosis (n=30), but in a different patient subset (only 17% of cases were identified by both methods). The VAP rate per 1000 mechanical ventilator days for the checklist and clinician diagnosis was 25.9 and 26.7, respectively. The item 'inflammatory response' was most associated with the first episode of physician-diagnosed VAP.

Conclusions: VAP rates using the checklist and physician diagnosis were similar to ranges reported internationally and in Australia. Of note, different patients were identified with VAP by the checklist and physicians. While the checklist items may assist in identifying patients at risk of developing VAP, and demonstrates synergy with the recently developed Centers for Disease Control (CDC) guidelines, decision-making processes by physicians when diagnosing VAP requires further exploration.

Strengths and limitations of this study

- The ventilator-associated pneumonia (VAP) checklist was developed by consensus with members of a bi-national professional organisation of intensive care physicians.
- The checklist was tested in a multisite prospective 30-day audit, demonstrating feasibility of data collection and external validity for calculating a contemporary VAP rate for intensive care units in Australia and New Zealand.
- Cases identified via the screening checklist differed from independent physician diagnosis of VAP, and microbiological analysis of pulmonary secretions, the gold standard for diagnosing VAP, was not part of the study's scope because of funding constraints.
- Other patient characteristics physicians used to diagnose VAP remains unknown, and further investigation is required to produce an acceptable surveillance definition for use in routine practice.
- Checklist items align with the revised surveillance approach from the US' Centers for Disease Control and National Health Safety Network.

INTRODUCTION

Treatment of critically ill patients commonly includes invasive mechanical ventilation (MV) in an intensive care unit (ICU). Iatrogenic lung injury, including ventilator-associated pneumonia (VAP), is a risk influenced by severity of illness, immune function, physiological reserve and duration of invasive ventilation.[1][2] Patients diagnosed with VAP have a longer ICU length of stay (LOS),[3] higher mortality rates[4] and higher costs of treatment.[3]

The reported rate of VAP in North American and European ICU settings is 1–53

cases per 1000 ventilator days,[3 5–7] affecting up to 30% of patients receiving MV.[6] While current definitions exist,[2 8–10] lack of accuracy and reliability in measurement remains a challenge for diagnosis.[11–15] This is reflected in lack of consensus about the diagnosis of VAP in Australia and New Zealand,[16] with few healthcare facilities routinely collecting VAP data.[17] While a 2005 study across 14 ICUs revealed a rate of 28%,[18] bi-national rates are currently unknown. Effective and systematic VAP prevention strategies are limited by this lack of consensus.

The study objectives were to develop and test a checklist for clinical surveillance of VAP; and conduct an audit in a sample of ICUs using the checklist to measure the current rate of VAP.

METHODS

A dual-method study design was used, involving a modified Delphi technique to construct the VAP checklist items; and a multisite prospective audit conducted in 10 ICUs across Australia (n=9) and New Zealand (n=1). Our decision on the sample size was pragmatic, based on similar previous Australasian studies,[18] piloting the time required for data collection, and the funding available to support site-based data screening and daily data collection for 1 month across the sites. The University's Human Research Ethics Committee approved the Delphi study. For the audit phase, ethics and local clinical governance approval was obtained from the Human Research Ethics Committees of a lead clinical site, each of the participating sites, and then ratified by the University Committee. The need for individual informed patient consent was waived by the lead site Committee, as the study was deemed low risk.

Checklist development

A list of clinical characteristics of VAP was initially developed from a survey constructed using current studies, including previously published criteria for VAP.[19–21] A draft survey was sent to the Quality and Safety (Q&S) Committee of the Australian and New Zealand Intensive Care Society (ANZICS), who reviewed the items as experts for face validity, and recommended minor changes. This revised version was then distributed to all ANZICS members using SurveyMonkey (Palo Alto, California, USA; December 2012 and January 2013).

Respondents were requested to rate their agreement on a four-point Likert scale for each criterion, provide comment and list any other diagnostic criteria they used. Item concordance was set at >80% agree/agree strongly. Content analysis was conducted on free-text fields for two items on standardised VAP criteria and incorporated into items. Validity of the results was checked during team discussions, and members of the ANZICS Q&S Committee reviewed the second draft for face validity. The checklist was then pilot tested at a volunteer site

and further refinements made for the final version (see online supplementary additional file 1).

Prospective audit

Sites were invited to participate by the ANZICS executive via email; of 15 expressions of interest received 10 were selected based on level of service and geographical location;[22] we estimated that an audit of this sample size over a 30-day period would provide an accurate estimate of VAP rates binationally.[15 18 22 23]

Data collection

A 28-item case report form (CRF) was developed, incorporating the VAP checklist and data on clinical characteristics, and patient demographics (see online supplementary additional file 2). Site-based research coordinators were trained in completion of the checklist and related CRF and data dictionary prior to data collection. Site investigators screened for eligible patients daily, using the following inclusion criteria: ICU patients >16 years old, invasively mechanically ventilated for >72 h, with no treatment limitation orders. Data collection started for study participants after 72 h of MV. Data were collected prospectively for all enrolled patients until ICU discharge or end of data collection (8 July—2 August 2013). Independent physician diagnosis of VAP was identified from patient medical records to enable comparisons with the checklist.

Statistical analyses

Patient characteristics were compared for those who had VAP reported according to the checklist or physician diagnosis, and those who had not. Analyses were by independent t tests or Wilcoxon rank-sum tests for continuous data and Fisher's exact tests for categorical data. A total VAP checklist score was calculated as the sum of each of the items (each item scoring '1'; range 0–5). The VAP rate was calculated as: VAP reported or diagnosed/total number of ventilator days×1000 for enrolled patients, and reported for: the number of patients positive for four (items 1–4) or all five checklist items; and the number of patients independently diagnosed with VAP by physicians.

A generalised estimating equation (GEE) model, using a logit function with an exchangeable correlation structure (conceptualised as an extension of logistic regression models with repeated measures analysed longitudinally[24]), enabled investigation of relationships between positive reports of items in the checklist (independent variables) and physician diagnosis (dependent variable) over time.

RESULTS
Checklist development

The survey response rate for ANZICS members was 16% (n=79/485). Most respondents (78%) worked in a tertiary-level ICU (College of Intensive Care Medicine

(CICM) level III.[25] Years of experience since obtaining their specialty qualification was approximately 25% each for <5, 6–10, 11–20 and >20 years. One-third indicated that VAP was monitored in their ICU, and 14% reported using standardised criteria for diagnosis. There was a >80% 'agree/strongly agree' rating for several items comprising published standardised criterion for VAP diagnosis (including statements related to gas exchange, respiratory secretion characteristics and radiological changes). The final consensus-developed VAP checklist is noted in table 1, with the five items listed in order from least to more invasive assessments.

Multisite audit
ICU and patient characteristics
The study units, all located in public hospitals, included seven tertiary referral (level III), one level II and two level I ICUs.[25] The contribution of patients from each participating site and ICU bed numbers are illustrated in figure 1. The units ranged in size from 14 to 58 beds, and were located in five jurisdictions across Australia and one in New Zealand. Study ICUs represented 20% (7/35) of the tertiary units binationally.[26] Some units reported policies related to minimising or preventing VAP: seven practised a policy of ensuring patients were positioned with the head of the bed elevated >45° most of the time; four routinely used subglottic suction endotracheal/tracheostomy tubes; and five indicated that mouth care with chlorhexidine (any concentration) was routine practice. One unit reported the use of all three preventative measures.

A final sample of 169 patients mechanically ventilated for >72 h were enrolled from initial screening of 345. Data were collected for 1692 bed-days during the study period, including 1122 days when patients received >12 h of MV per day. The contribution of patients from each participating site and ICU bed numbers are illustrated in figure 1. Mean participant age was 59.7 years,

65% were male and 64% were admitted with a medical diagnosis (25% had either a cardiac or respiratory diagnosis). The median durations for MV and ICU LOS were 7 and 11 days, respectively (see table 2).

Patients screened or diagnosed with VAP
All five characteristics of VAP from the screening checklist were reported in only 10 patients. Given the low incidence of actual laboratory assessments performed for sputum growth (discussed in later section), exclusion of item 5 resulted in 29 patients screened as having VAP (17.2% of sample). The VAP rate for checklist items 1–4 was 25.9 per 1000 mechanical ventilator days (8.9 when all 5 items were present). Checklist items with the highest number of positive reports were: arterial oxygen tension (PaO_2) to fraction of inspired oxygen (FiO_2) ratio (PF ratio; item 1; n=855), 'inflammatory response' (item 4; n=793) and 'sputum changes' (item 2; n=306). The most commonly reported subitem within 'inflammatory response' was 'white cell count ≤ 4 or ≥ 12 cells 10^9/L for 2 days' (n=552). As noted in table 2, patients identified with VAP using the checklist were more likely to be male (p=0.05), ventilated for ≥ 4 days (p=0.002), had an ICU LOS 5 days longer than those patients with no checklist items present and have a primary non-operative trauma diagnosis (p=0.05).

Treating physicians independently clinically diagnosed 30 patients with VAP (documented in patient records; 17.8% of sample), reflecting a slightly higher VAP rate of 26.7 per 1000 mechanical ventilator days. Patients with a physician diagnosis of VAP had similar characteristics—MV 2.5 days longer (p=0.04) and an ICU LOS 3 days longer than those patients with no physician VAP diagnosis (p=0.03). A higher proportion of patients with a non-operative cardiac diagnosis were subsequently diagnosed with VAP (p=0.05), while few patients with a non-operative respiratory diagnosis developed VAP from either group.


Table 1 VAP checklist items

	Item	Definition
1	PaO_2/FiO_2 ratio* ≤ 300 mm Hg	Deterioration in gas exchange over past 24 h in the absence of cardiogenic pulmonary oedema or pulmonary disease
2	Sputum changes	A change in sputum characteristics, increased volume or colour changes (yellow or green)
3	CXR infiltrates	New localised or diffuse infiltrates on a single CXR (not explained by cardiogenic pulmonary oedema or pulmonary disease)
4	Inflammatory response	≥ 1 of the following (in the absence of immunocompromise)
	A.↑ Temperature	New and persistent (past 24 h) elevated body temperature ≥ 38°C (or >37.5°C if concurrent antipyretic medication administration)
	B.WCC	WCC ≤ 4 or ≥ 12 cells 10^9/L for 2 days
	C.↑ Inflammation	Elevated serum inflammatory markers: C reactive protein (>100 mg/L) or procalcitonin (>2.5 ng/L) for a single blood test
5	Microbial growth	Microbial growth in tracheal secretions obtained by tracheal suctioning or bronchoscopy (ie, >25 neutrophils per low power field or equivalent)

Three days after a patient is started on mechanical ventilation, are any of the following clinical characteristics present?
*PaO_2/FiO_2 ratio=arterial oxygen tension/fraction of inspired oxygen.
CXR, chest X-ray; VAP, ventilator-associated pneumonia; WCC, white cell count.

Figure 1 Contributions of participating sites: number of intensive care unit (ICU) beds and patients enrolled (College of Intensive Care Medicine (CICM) level[25]).
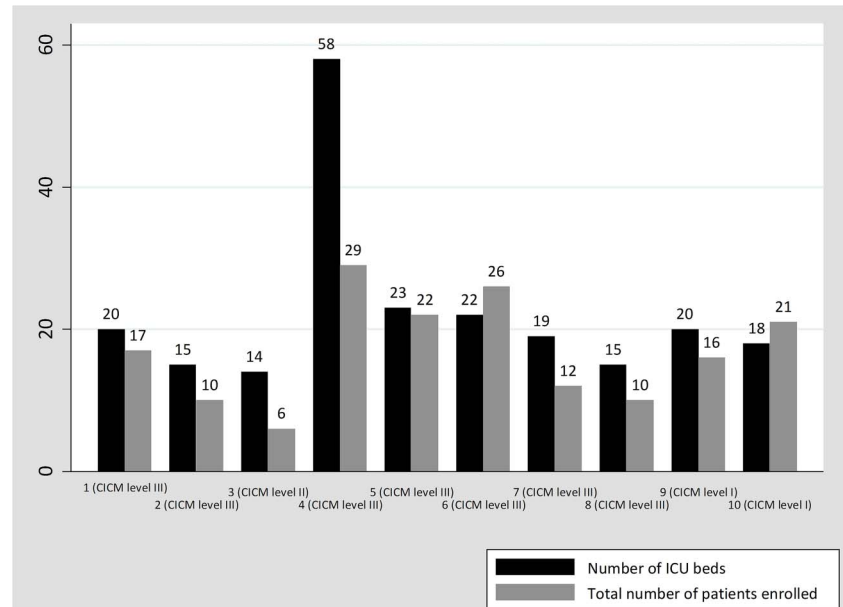
Of note, however, only five patients (17%) had documented VAP using both the screening checklist (4 items) and physician diagnosis. These patients (4 male: 1 female) had a moderate-to-high severity of illness score (APACHE II score range 12–23), received MV for 11–27 days and were treated in ICU for 13–57 days. Three patients had documented VAP using all five checklist items and physician diagnosis.

An unadjusted OR for 'inflammatory response' (item 4) of 3.88 was noted when examining associations between the checklist items and physician diagnosis; patients with a positive recording had a fourfold increase in the risk of receiving a physician diagnosis of VAP compared with patients who did not have a positive report. ORs for other items were not statistically significant (range 1.27–2.07; see table 3).

Post hoc analyses between checklist or physician diagnosis of VAP and microbial growth (infected or colonised sputum) provided no significant associations, with the small number of identified VAP cases who received microbiological sputum reports precluding further analyses (see online supplementary additional file 3 for further details). In relation to administration of antimicrobials, descriptive analyses revealed a higher proportion of patients with a physician diagnosis of VAP (83%) received antimicrobials compared with patients identified using the VAP four-item checklist (72%). See online supplementary additional file 3 for proportions and details reported for each case group. No further analyses were preformed because of the small sample size and the overlap between checklist and physician cases (n=5).

DISCUSSION
Key findings compared with previous studies
Study participants had a longer ICU LOS, and higher severity of illness scores and mortality rates compared

with all mechanically ventilated patients, but a lower median length of MV (7 vs 11 days) and ICU LOS (11 vs 30 days) when compared with patients receiving MV for >3 days in Australian and New Zealand ICUs.[26]

A VAP incidence of 17% of patients for the checklist was within the range frequently reported in the international literature (9–27%),[27] but lower than other reports (29%[28]; 30%[6]; 38%[29]) including from Australia (28%).[18] This may be explained in part by the inclusion criteria, with patients who received short-term ventilation excluded, and enrolment of patients with an extended ICU LOS, an associated higher mean APACHE II score (20 vs 14) and higher mortality rate (23% vs 10%).[22] It is also possible that misdiagnosis was responsible for some VAP reports, and the 'true' rate may be lower (three patients with a clinician diagnosis of VAP had cardiogenic shock and one had aspiration pneumonia). 'Overlapping diagnoses' confounding VAP rates has been previously reported.[30]

Little overlap between the patients identified by checklist and physician diagnosis was unexpected. This discrepancy may reflect continued lack of agreement in the Australian and New Zealand intensive care community, between what intensive care physicians think should happen (policy and guidelines) and what happens in actual practice, and reinforces a continued need for an agreed surveillance definition.

The only checklist item associated with a physician diagnosis of VAP was 'inflammatory response', reflecting a fourfold increase in the risk of receiving an physician diagnosis of VAP compared with patients without a noted inflammatory response. This finding may reflect the evolving contemporary view of VAP as one element in a continuum of airway changes including inflammation.[31] The absence of any other item associated with a VAP physician diagnosis may have been a result of small sample sizes for other items. New infiltrates on chest

Table 2 Study patient characteristics, including those screened or diagnosed with VAP

Characteristic	Overall sample (n=169)	Screened using VAP checklist items 1–4			Diagnosed by an intensivist		
		VAP (n=29)	No VAP (n=140)	p Value	VAP (n=30)	No VAP (n=139)	p Value
Age, mean±SD (years)	59.71±15.98	59.78±17.03	59.71±15.83	0.98*	58.60±18.63	59.95±15.72	0.67*
Gender, n (%) (male)	110 (65)	22 (76)	88 (63)	0.05†	21 (70)	89 (64)	0.53†
BMI, mean±SD	28.79±7.28	28.95±7.21	28.75±7.32	0.90*	28.28±7.01	28.90±7.36	0.69*
APACHE II score, mean±SD	20.61±7.08	18.76±6.30	21.01±7.19	0.09*	18.63±4.60	21.04±7.45	0.09*
Charlson, median (IQR)	1 (0–2)	1 (0–2)	1 (0–2)	0.23‡	1 (0–2)	1 (0–2)	0.23‡
Smoking, median (IQR), (years)	0 (0–10)	0 (0–6)	0 (0–13.5)	0.55‡	0 (0–10)	0 (0–12)	0.71‡
Smoking, dichotomised, n (%)	–	8 (27)	45 (28)	0.62†	9 (30)	44 (31)	0.86†
ED admission, n (%)	38 (22)	8 (27)	30 (21)	0.47§,¶	7 (23)	31 (22)	0.71§,¶
Readmission ICU, n (%)	15 (9)	4 (14)	11 (8)	0.31§	1 (3)	14 (10)	0.47§
Mechanical ventilation, median (IQR) (chart days)	7 (5–12)	11 (7–16)	7 (5–11)	0.002	9.50 (7–14)	7 (5–12)	0.04
ICU LOS, median (IQR) (days)	11 (8–19)	15 (10–22)	10 (7–17)	0.01	13 (10–20)	10 (7–17)	0.03
Hospital LOS, median (IQR) (days)	30 (16–43)	29 (20–49)	24 (14–40.5)	0.11	26 (17–48)	25 (15–41)	0.92
Alive at 30 days, n (%)	131 (77)	24 (83)	107 (75)	0.46†	21 (70)	110 (79)	0.27†
Non-operative diagnosis, n (%)	108 (64)	22 (76)	86 (61)	0.13†	18 (60)	90 (65)	0.62†
Cardiac, n (%)	25 (23)	5 (17.5)	20 (14)	0.41	8 (27)	17 (12)	0.05
Respiratory, n (%)	28 (26)	4 (14)	24 (17)	0.45	1 (3)	27 (19)	0.01
Gastrointestinal, n (%)	9 (8)	0	9 (6.5)	0.17	2 (7)	7 (5)	0.50
Neurological, n (%)	10 (9)	2 (7)	8 (6)	0.54	3 (10)	7 (5)	0.50
Sepsis, n (%)	14 (13)	4 (14)	10 (7)	0.20	0	14 (10)	0.60
Trauma, n (%)	13 (12)	5 (17.5)	8 (6)	0.05	4 (13)	9 (7)	0.18
Other, n (%)	9 (8)	2 (7)	7 (5)	0.47	0	9 (7)	0.15
Operative diagnosis, n (%)	61 (36)	7 (24)	54 (39)	0.13†	12 (40)	49 (35)	0.62†
Cardiac, n (%)	29 (47)	4 (14)	25 (18)	0.41	6 (20)	23 (17)	0.41
Respiratory, n (%)	0	0	0	–	0	0	–
Gastrointestinal, n (%)	10 (16)	1 (3)	9 (6.5)	0.46	0	10 (7)	0.13
Neurological, n (%)	10 (16)	1 (3)	9 (6.5)	0.46	4 (13)	6 (4)	0.08
Trauma, n (%)	10 (16)	1 (3)	9 (6.5)	0.46	2 (7)	8 (6)	0.56
Other, n (%)	2 (5)	0	2 (1)	0.68	0	2 (1)	0.68

*Independent t test (unequal variances) two tailed.
†χ^2 Test.
‡Wilcoxon rank-sum (Mann-Whitney) test.
§Fishers exact test (one-sided).
¶Analysis included comparisons for all locations of patients prior to ICU admission.
APACHE, Acute Physiology and Chronic Health Evaluation (on admission); BMI, body mass index (height and weight available for n=145); ED, emergency department; ICU, intensive care unit; LOS, length of stay; VAP, ventilator-associated pneumonia.

X-ray was found by others to be highly indicative of a diagnosis of pneumonia[27] but was not the case in our study. Two possible explanations are evident: 'overlapping diagnoses' (eg, acute lung injury), and the under-reporting of chest X-ray changes in patient records. Note also that we used physician diagnosis as a pragmatic comparator reflecting routine practice.

'Microbial growth in tracheal secretions' (item 5) did not contribute to the explanatory model, perhaps because of low documented laboratory reports, and possible collinearity with 'change in sputum characteristics' (item 2). Pathology services at study sites contacted prior to the audit confirmed that a quantitative report for the presence of white cells in sputum was routine microbiology reporting. However, in practice, many site investigators reported that their organisation's pathology services did not provide this. In the absence of a pathology report, site data collectors responded 'no' to this item. Arguably, presence of 'sputum changes' is a visual cue for microbial/white cell debris, and likely to manifest in a quantitative report of '>25 neutrophils per low power field or equivalent' in sputum obtained by tracheal suctioning. Neither item however contributed significantly to the GEE model (ORs 1.27 and 1.52, respectively).

Study strengths and limitations
Our approach to data collection was comprehensive but feasible; the latter important for quality indicator data to be collected sustainably. Our VAP rate (17%) using checklist items 1–4 was in ranges reported in the international literature, suggesting congruence with approaches used by others. The study sample involved

Table 3 VAP checklist items associated with clinician diagnosed VAP: multivariate analysis model (all 5 items)

Item number	Item	OR	95% CIs	p Value
1	PF ratio ≤300 mm Hg (n=855)	1.58	0.61 to 3.99	0.338
2	Sputum changes (n=306)	1.27	0.55 to 2.86	0.566
3	CXR infiltrates (n=143)	2.07	0.82 to 5.19	0.115
4	Inflammatory response (n=793)	3.88	1.38 to 10.98	0.010
5	Microbial growth (n=11)	1.52	0.59 to 3.87	0.375

PF ratio, PaO_2/FiO_2 ratio.
CXR, chest X-ray; PaO_2/FiO_2 ratio, arterial oxygen tension/fraction of inspired oxygen; VAP, ventilator-associated pneumonia.

differing levels of ICU conferring potential external validity. A sample size of 10 ICUs was however small, with any representativeness to the Australian and New Zealand context probably confined to tertiary-level units; note also that only New Zealand ICU was involved. Examination of longitudinal relationships between physician diagnosis and checklist items over time enabled insight into the contribution of each item, and a quantitative measure of the increased possibility of a diagnosis of VAP in the presence of an inflammatory response.

Independence between checklist data collected by site-based investigators and diagnosis of VAP by independent physicians was both a study strength and weakness. Assessment using the checklist was unbiased, but the decision-making process for a physician diagnosis was not documented and remains unknown. Use of physician diagnosis as a comparator was therefore a limitation as individual physicians appeared to use a different set of criteria to diagnose VAP. Given the disparate cases identified between the checklist and physicians, it would have been useful to incorporate in the methods a review of case notes by an independent panel of clinicians for verification of likely VAP diagnosis, whether the clinical course reflected pneumonia, and to identify any predictors and patterns in antibiotic prescription. Other information, such as findings from thoracic CT scans or autopsy results, would also have been useful, but were not abstracted a priori from patient notes.

Our study was not funded for microbiological analysis of pulmonary secretion[11] on all screened patients. Independent microbial analyses were used when available through routine practice, but were not a requirement for study inclusion, and were only reported in 7% of patients. This variability in reporting was therefore a limitation given that this was one of the VAP checklist items (5, 'sputum growth'). Our analyses did however indicate that 'sputum changes', item 2, may be a proxy albeit less sensitive and objective indicator than a formal microbiological report.

Additional limitations are noted. There may be differences between physicians who were members of ANZICS and those who were not. In addition, four-fifths of respondents worked in tertiary-level ICUs. We are therefore unsure whether our sample was truly representative of intensive care physicians practising across Australia and New Zealand. There was evidence of local unit

consensus when completing the survey, so it appears likely that input from intensivists was higher than 16%. (Attempts were made to increase survey participation.) Communications from intensivists indicated that some ICU directors nominated a spokesperson to complete the VAP survey. The number of physicians providing input to the survey therefore probably exceeded 79. This unintentional unit-level approach may have limited variability in the full-text responses, and the sampling may have been biased to physicians who were convinced about the need for VAP surveillance (75% respondents agreed that VAP surveillance should be routine) or ICUs in which VAP monitoring was practised. It appeared that there were few responses from 'VAP sceptics'.

Implications for practice
Our consensus-derived checklist items were equivalent to items from the Clinical Pulmonary Infection Score (CPIS): temperature, blood leucocytes, tracheal secretions, oxygenation, radiography, tracheal aspirate culture.[20] This outcome may have occurred because the CPIS instrument was a source document during our initial modified Delphi survey, and retained as these clinical characteristics resonated with previous training and contemporary clinical experiences of practising intensive care physicians.

Checklist items are also similar in content to a revised surveillance approach from the US Centers for Disease Control (CDC) and National Health Safety Network (NHSN).[31] An algorithm is used to define a continuum of: a ventilator-associated condition, infection-related ventilator-associated complications and possible/probable VAP. A comparison of the features of our VAP checklist and the CDC/NHSN guidelines are presented in table 4. This approach formally reconceptualises inflammatory and infectious processes associated with an artificial airway and MV as a continuum of 'events'.[31] While initial studies highlighted some methodological concerns,[32 33] recently the new CDC/NHSN approach demonstrated superior reliability and validity compared with their former VAP definition, and may enable automated surveillance.[34]

Similarities between our definition and the CDC/NHSN approach and the relative ease with which site investigators used the VAP checklist suggests that our consensus-based checklist may be an appropriate

Table 4 Comparison of VAP surveillance criteria

Australian and New Zealand-developed checklist items	CDC/NHSN-developed three-tiered elements[33]	
1. PaO_2/FiO_2 ratio ≤300 mm Hg: decreased gas exchange in past 24 h (no cardiogenic pulmonary oedema/pulmonary disease)	Increased daily F_iO_2 increases of ≥0.2 or PEEP values ≥3 cm H_2O)=**VAC**	
4. Inflammatory response: ≥1 of the following (when no immunocompromise)	On or after day 3 of MV and within 2 calendar days of worsening oxygenation:	
A. New/persistent ↑ temperature ≥38°C	> 38°C or	and new antimicrobials
B. WCC ≤4 or ≥12 cells 10^9/L for 2 days	WCC ≤4 or ≥12 10^9/L	started=**IVAC**
C. Elevated C reactive protein (>100 mg/L) or procalcitonin (>2.5 ng/L)	NA	
5. Microbial growth: >25 neutrophils per low power field in tracheal secretions	Purulent respiratory secretions containing >25 neutrophils per low power field=**VAP**	
2. Sputum changes: increased volume, or colour changes (yellow or green)	NA	
3. CXR infiltrates: new localised or diffuse infiltrates on single CXR (no cardiogenic pulmonary oedema/pulmonary disease)	NA	

CXR, chest X-ray; IVAC, infection-related ventilator-associated complication; MV, mechanical ventilation; NA, not applicable; PaO_2/FiO_2 ratio, arterial oxygen tension divided by fraction of inspired oxygen; PEEP, positive end-expiratory pressure; VAC, ventilator-associated condition; VAP, ventilator-associated pneumonia; WCC, white cell count.

adjunct for automated surveillance from electronic medical records in Australia and New Zealand.

Recommendations for further research

Our approach does limit interpretation for some findings; the checklist items demonstrated mixed reliability and validity, with 'inflammatory response' the only item strongly associated with a clinician diagnosis of VAP. Given the ORs (but not statistical significance) for other items, we recommend that the checklist continue to be evaluated in practice with larger sample sizes and evaluation of patient outcomes to further test its utility as a screening tool for VAP.

Future work could explore similarities between the characteristics of patients diagnosed with VAP using both the checklist and independent physician diagnosis to refine checklist items. This could potentially increase the identification of patients that would benefit from treatment that differentiates a generalised inflammatory response from an infection.

Importantly, and as noted earlier, we are unclear about the actual decision-making processes used by clinicians. With little overlap in identified patients between physician diagnosis and the screening checklist, there are clearly other factors involved during the diagnostic process. Further exploration of the decision-making process of individual physicians when considering VAP, and the rationale for any related antibiotic prescribing is therefore required.

CONCLUSIONS

This consensus-developed 'VAP checklist' with four items: PF ratio, sputum changes, chest X-ray infiltrates and inflammatory response, identified 17% of this sample with characteristics of VAP, reflecting an incidence of 25.9 per 1000 mechanical ventilator days. Patients identified from independent physician diagnosis

of VAP differed from those using the checklist, and requires further investigation to enable development of an acceptable surveillance definition for use in routine practice.

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