ORIGINAL ARTICLE

Intensive care nurses on social media: An exploration of knowledge exchange on an intensive care virtual community of practice

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Abstract

Aims and objectives: To explore the nature of knowledge exchange on a multi-disciplinary Australasian intensive care virtual community of practice, "ICUConnect."

Background: Current organisational structures and cultures constrain the social networks of healthcare professionals, limiting access to contemporary best practice knowledge. While virtual communities can facilitate knowledge and clinical expertise exchange in professional networks, their effectiveness has not been established.

Design: A sequential mixed-methods design with a quantitative core and qualitative supplementary component was used to explore the content of discussions from an intensive care virtual community. SRQR has been used to report this study.

Methods: Email archives of an intensive care listserv (2003–2013) were mined using a two-stage sampling technique to identify discussion threads (with >2 posts) concerning ventilator or airway practices (cluster) and two sets of 20 threads (stratified across years). Summative content analysis was used to examine both manifest and latent content.

Results: Forty threads containing 326 emails posted by 133 individuals from 80 organisations were analysed. Nurses contributed 68% (55% were in clinical leadership roles) and physicians 27%. Three subject areas were identified: clinical practices (71%); equipment (23%); and clinical governance (6%). "Knowledge-requested" and "knowledge-supplied" posts were categorised as follows: experiential and explicit (33% and 16%, respectively); experiential (27% and 35%); or explicit (40% and 17%). Knowledge supplied was also categorised as "know-how" (20%); "know-why" (5%) or "no knowledge" exchanged (6%). The central construct of virtual community work was identified with six elements that facilitated participation and knowledge exchange including: (a) the discussion thread; (b) sharing of artefacts; (c) community; (d) cordiality; (e) maven work; and (f) promotion of the VC. Members asked questions

to benchmark their practice, while those who answered were focused on ensuring that best practices were delivered.

Conclusions: ICUConnect reflected characteristics of a virtual community of practice, enabling key benefits for members and the broader Australasian intensive care community, especially access to best practice knowledge from clinical experts.

Relevance to clinical practice: This study demonstrated that a practice-based VC can function effectively as a VCoP to establish an effective professional network where members have access to up-to-date best practice knowledge. Healthcare organisations could leverage VCs to support the professional development of HCPs and ensure that local clinical practices are based on contemporaneous knowledge. Participation by nurses in these communities facilitates individual professional development and access to important clinical knowledge and expertise, and ultimately reinforcing the unique position of nursing in delivering effective, consistent high-quality patient care.

KEYWORDS

communities of practice, computer communication networks, evidence-based practice, experiential learning, learning, nurses, online, professional competence, social learning, social media

Hi everyone,

This is a topic that "works the room" within our environment (particularly the tearoom when they are due), but can people give me an idea when they change the ventilator circuits and what current evidence you use to justify this procedure. The same can be applied to closed suction systems I suppose, which we also use.

Retrieval nurse and equipment manager,
Tertiary referral ICU

1 | INTRODUCTION

While multi-disciplinary virtual communities of practice (VCoP) have the potential to facilitate knowledge and clinical expertise exchange within professional networks and across organisations (Antonacci, Fronzetti, Stefanini, & Gloor, 2017; Currie & White, 2012; McGowan, 2012), their effectiveness in practice needs to be established. This article reports findings from a sequential mixed-methods design that explored the nature of knowledge exchanged within an intensive care-based virtual community (VC) in Australia, "ICUConnect." The study formed part of a qualitatively driven multiple-methods programme of research underpinned by pragmatism where three concurrent studies examined inter-related aspects of the ICUConnect listserv: (a) the professional social network (Rolls, Hansen, Jackson & Elliott. 2014; (b) knowledge exchange and on-line participation (present study); and (c) why healthcare professionals (HCP) join and remain members (Rolls et al., 2016a).

> **What does this paper contribute to the wider global clinical community?**
>
> - For clinicians to deliver effective clinical practices, knowledge in their local practice community must be challenged and replenished through professional networks that extend beyond organisational boundaries.
> - Participation in multi-disciplinary speciality-specific virtual communities of practice facilitates professional development for nurses, provides clinical leaders with valuable knowledge for application in local settings and enhances and highlights the unique contribution of nurses to patient care.
> - To ensure that local clinical practices are based on contemporaneous best practice knowledge, healthcare organisations should encourage participation of their employees in online professional communities.

2 | BACKGROUND

Healthcare organisations face two significant challenges for their patients to experience optimal outcomes: delivery of best clinical practices based on contemporaneous evidence and supporting the professional development of clinicians. Currently, significant clinical practice variability exists, leading to suboptimal patient outcomes (Braithwaite & Donaldson, 2016), which may be attributable

to ineffective social networks (Hollingsworth et al., 2015). There is increasing interest in the use of VCs to overcome professional and organisational barriers (Rolls et al., 2016b) and broaden the scope of HCP social networks, therefore enabling reach to a range of peers and facilitating access to a broad base of expert knowledge beyond local healthcare organisations. In the following section, the types of knowledge that HCPs need for practice will be explored followed by review of the evidence base on their use of VCs to obtain this knowledge.

2.1 | Knowledge for healthcare professionals

Western healthcare practices are predominantly underpinned by research evidence (Marshall, West, & Aitken, 2011). Evidence-based practice (EBP) reflects clinical decision-making by combining best scientific evidence, patient considerations and clinical expertise (Sackett, Rosenberg, Muir Gray, Haynes, & Richardson, 1996). In practice, EBP conforms to a pragmatic epistemology (James, 1907–2013), reflective of mind lines developed by groups of clinicians who deliver practices based on a combination of theoretical, explicit or codified and collective tacit knowledge, and reinforced through social networks with other clinicians and patients (Wieringa & Greenhalgh, 2015).

When considering the application of knowledge to professional practice, the know-what, know-how and know-why taxonomy reflect both the evolution of professional competence and how different forms of knowledge come together in action (Garud, 1997; Lee-Kelley & Turner, 2017). Know-what knowledge is explicit or codified knowledge that prepares a practitioner to know what actions are appropriate for a limited number of clinical situations (King, 2009). Know-what knowledge is developed through "learning by doing" or practice experiences, so that know-how knowledge is accumulated, enabling a novice to develop and function more independently (Garud, 1997; Lee-Kelley & Turner, 2017) within the presence of distracting information (King, 2009).

Know-how knowledge also develops during interactions with professional colleagues, including within organisational routines, processes and social networks (Garud, 1997; Lee-Kelley & Turner, 2017). Know-how knowledge therefore includes articulation of the problem, solution and rationales for a specific practice situation. Novice HCPs require this experience to develop the "know-how" or specific practice (craft) knowledge of their discipline, enabling safe, effective and independent performance (Kothari et al., 2012).

Know-why knowledge evolves as professionals acquire significant experience and reflection, enabling a deeper understanding of how to combine scientific (know-what) with acquired knowledge (know-how) and apply this to novel and complex situations (King, 2009; Lee-Kelley & Turner, 2017). This learning by studying occurs when a professional actively examines or experiments to develop a deeper understanding of how the underlying principles and theories interact in given situations (Garud, 1997). Know-why is embodied in understanding of the problem, working through alternative solutions and rationales, and application of scientific evidence to a specific situation (Lee-Kelley & Turner, 2017).

In health, clinical expertise is analogous to "know-why" knowledge and is central to the original articulation of EBP (Sackett et al., 1996) and providing quality patient care (Manley, Hardy, Titchen, Barbett, & McCormack, 2005). Integral to expertise are both mastery of a specific bounded knowledge and the practice domain, and the ability to span boundaries and participate in other networks (Kothari, Hovanec, Hastie, & Sibbald, 2011). Access to clinical expertise is an imperative for nursing, given the variability in quantity and quality of empirical evidence to guide practice (Rolls & Elliott, 2008), within the context of an ageing workforce (Cioffi, 2012). Table 1 maps these knowledge types to common clinical practices.

Note that know-what, know-how and know-why knowledge do not represent a continuum, but are an iterative process as new knowledge develops in practice and through interactions with colleagues (Garud, 1997). Within a clinical unit or organisation, know-what and know-how reflect negotiated norms that become embedded within local and organisational practices and routines (Atherton, 2013). This view of knowledge therefore emphasises the importance of the social and human aspects of knowledge and development of professional competence through experience within a practice community (Brown & Duguid, 1991; Wieringa & Greenhalgh, 2015).

To have access to the most appropriate knowledge for practice in any given situation, the professional development of clinicians must be supported through local and organisational communities of practice (CoP; Kothari et al., 2011). Knowledge within local units must therefore be continually replenished by effective knowledge management activities including professional networks and active boundary crossing (Kothari et al., 2011). In this context, a boundary is a barrier or demarcation between organisational units (e.g., wards or facilities), HCP type (e.g., physician, nurse or physiotherapist) or speciality type (e.g., intensive care vs. emergency) that has the potential to interrupt knowledge flow (Akkerman & Bakker, 2011). Of note, both nurses and physicians rely on intra-personal (theoretical and experiential) knowledge before turning to close credible colleagues when personal knowledge stocks are unable to provide an answer (Kostagiolas, Korfiatis, Kourouthanasis, & Alexias, 2014; Marshall et al., 2011). Thus, demonstrating the need for effective communication channels in local social networks.

2.2 | Healthcare virtual communities' and knowledge exchange

Virtual communities are formed when a group of people with a common interest meet online using social media, creating a collaborative space to exchange knowledge (Barnett, Jones, Bennett, Iverson, & Bonney, 2012; Murad et al., 2017). A recent integrative review found that since the early 1990s, HCPs have used VCs to network with peers for several reasons including: (a) to access relevant speciality knowledge; (b) overcome professional isolation; (c) foster collaboration and mentoring; (d) facilitate professional development; (e) improve clinical practice through research and evidence translation; and (f) to obtain clinical advice (Rolls et al., 2016b).

Knowledge type	Definition	Healthcare example
Experiential	Knowledge learnt through experience or practice (Brown & Duguid, 1991)	Ability to apply dressing to central line
Explicit	Knowledge that has been externalized from an individual, or codified, and can be transmitted to another via an understandable language (Brown & Duguid, 1991)	Published research, clinical practice guidelines, national standards
Tacit	Knowledge that emerges in a specific moment when an expert is faced with a novel situation but is able to act because of expertise (Brown & Duguid, 1991)	Unconscious understanding of the amount of pressure to apply when inserting a vascular access device based on previous experience, including factors such as depth of vessel and skin type
Know-what	Scientific and theoretical discipline knowledge that enables them to practice as novice professionals (King, 2009)	Process of dressing a central venous catheter (CVC)
Know-how	Practice knowledge that combines know-what with clinical experience so that practitioners are able to perform safely and independently under most circumstances (Kothari et al., 2012)	Dress a CVC following facility- or unit-specific guidelines
Know-why	Clinical expertise developed through extensive experience and study of practice so that the practitioner is able to perform independently regardless of circumstances (King, 2009)	Vary CVC dressing because patient has poor skin integrity

Online discussions are commonly characterised by the exchange of experiential speciality-specific knowledge (Morken, Bull, & Moen, 2009), rather than evidence-based knowledge (Abrahamson, Fox, & Anderson, 2013). Similar to non-HCP VCs, exchanges also commonly occur between a minority of members (Morken et al., 2009; Rodriguez-Recio & Sendra-Portero, 2007; Stewart & Abidi, 2012). A symbiotic relationship develops between the culture of a virtual community and its members, where knowledge sharing is facilitated by a collectivist, altruistic, respectful noncompetitive online environment (Rolls et al., 2016b). Importantly but unsurprisingly, antisocial online behaviours have a negative effect on member engagement (Rolls, Kowal, Elliott, & Burrell, 2008).

A VC that evolves to a VCoP that actively facilitates knowledge sharing and professional development displays seven key attributes (see Figure 1; Barnett et al., 2012; Chang, Hsu, Hsu, & Cheng, 2014). Where there is a diverse multi-disciplinary membership from multiple organisations, two important features exist: availability of multiple perspectives and experiences (Barnett et al., 2012; Chang et al., 2014; Murad et al., 2017) and crossing of structural, professional and pragmatic boundaries (Kothari et al., 2011). These features are key if VCoP members are to have access to new knowledge.

Previous studies on healthcare VCs have used online observation, content analysis techniques and interviews, enabling exploration of new knowledge and skills acquisition, how social construction of knowledge evolves through a discussion thread and the online

culture of a VC (Rolls et al., 2016b). Developing a comprehensive understanding of knowledge exchange on healthcare VCs was, however, limited because of common study limitations including inadequate descriptions of: (a) for the data corpus and/or unit; (b) the unit of analysis; (c) coding schema development and categories, with limited theoretical basis for categories; and (d) data evaluation, including inter-rater reliability analysis (Rolls et al., 2016b).

The current evidence base therefore leaves several important questions with limited answers. What knowledge do HCPs seek on VCs? What knowledge is provided and is this knowledge evidence or best practice-based? What intensive care issues, such as clinical practices, advice on equipment or safety issues, do clinicians seek help for online? How does the culture of the online community influence participation and knowledge exchange? This study was designed to consider these evidence gaps. Given the plethora and increasing use of social media, this study seeks to answer the question of whether healthcare VCoPs can facilitate knowledge and clinical expertise exchange within professional networks and across organisations.

2.3 | AIM

The aim of this study was to explore the knowledge content exchanged between members of an exemplar VC, ICUConnect. The
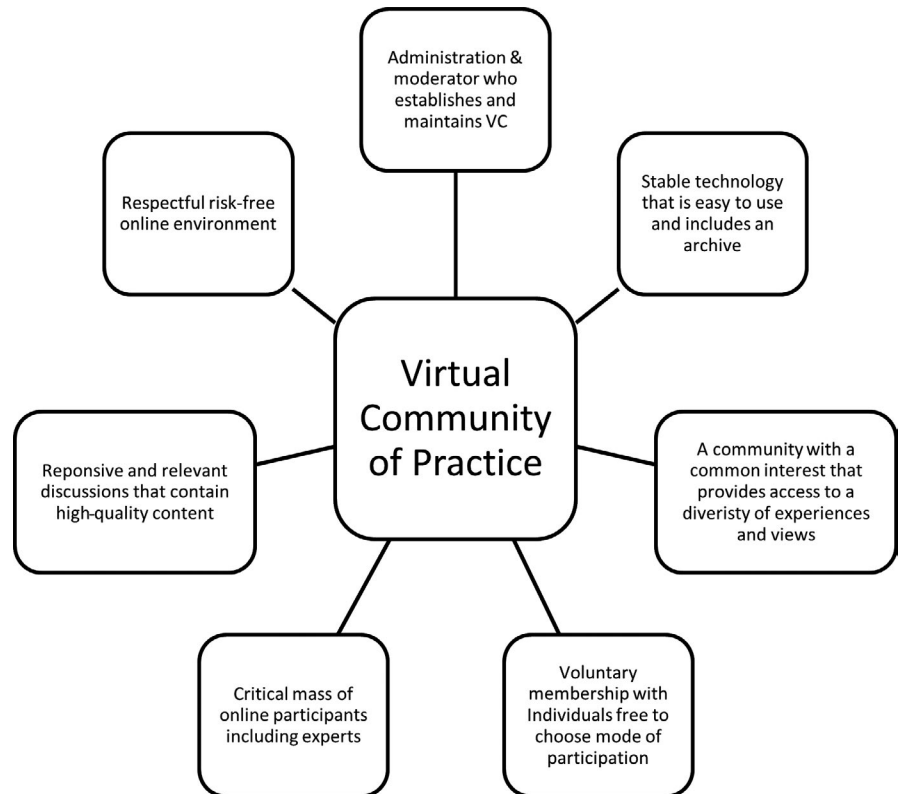
related research questions were as follows: (a) what was the nature of knowledge exchanged on an intensive care listserv? And (b) how was the online culture of ICUConnect embodied within discussion threads to facilitate knowledge exchange?

3 | METHODS

3.1 | Design

A sequential mixed-methods design with a quantitative core and qualitative supplementary component (Morse & Niehaus, 2016) was used to explore the content of discussions from an intensive care virtual community. The study was underpinned by pragmatism (James, 1907–2013) and informed by the theories of community of practice (CoP; Wenger, 2004) and diffusion of innovations (Rogers, 2003). An audit trail was developed using an Excel workbook for planning and recording research steps and managing manifest data, and an NVivo file for inductive content analysis. A research diary was also maintained for all steps using the NVivo memo function, to facilitate data interpretation and reflection. This study is presented according to Standards for Reporting Qualitative Research (SRQR; O'Brien, Harris, Beckman, Reed, & Cook, 2014) (see File S1).

3.2 | Reflexivity

Two authors (first and fourth were members of the VC, with the first author listserv moderator from 2005–2014) were intensive

care nurses with extensive clinical experience. The moderator role included managing member enrolment and ensuring online discussions adhered to VC etiquette. Individual members were able to directly post online without moderation, and no strategies were used to manipulate or promote discussions. No moderator-posted newsletters or new research posts were included in the data corpus. Author four was an observer and did not actively participate in discussions.

3.3 | Setting

The study setting was ICUConnect, a listserv created to facilitate communication and knowledge sharing between clinicians of the 43 adult ICUs in NSW, Australia. The VC was a large open VC as it was multi-organisational, with a high geographic dispersion and a stable heterogeneous membership (Rolls et al., 2014). The HCP profile included all members of the multi-disciplinary team (MDT) although the majority were nurses (84.8%, n = 884); physicians 6.5% (n = 68); industry 2.3% (n = 24); academics 2.1% (n = 22); healthcare managers 2.4% (n = 25); and allied health 1.7% (n = 18). Of significance, there are large numbers of intensive care (IC) leaders, including nursing unit managers (NUM), nurses responsible for ensuring local clinical practices reflect best practice through education, EBP or research (knowledge brokers [KB]) and ICU directors. Between 2004–2013, total membership grew from 130 to approximately 1,600, although a contemporary analysis of the demographic profile was not possible post-2009 due to changes in how member data were collated and time constraints preventing data cleaning.

3.4 | Sample

The sample (data corpus) was obtained using a two-stage (cluster and stratified) sampling approach to identify 40 discussion threads from ten years of discussion. Random sampling was not technically possible because of archival arrangements of the VC. Cluster sampling was initially used to identify threads related to a core component of intensive care practice with three or more emails between January 2004–December 2013. Email archives of the first author were searched using keywords reflective of clinical practices related to mechanical ventilation or airway management (see Table 2). Our previous research (citation redacted) found that HCP used VCs to exchange domain-specific experiential knowledge (Rolls et al., 2008), and an earlier evaluation of ICUConnect discussions found that this topic was the largest clinical subject group discussed (26%; 103/401). As 61 threads were identified, a second stage using stratified sampling was then completed with a random number generator (using Microsoft Excel, Microsoft Corporation, Redmond). Two data corpora were identified, with 20 threads each that included: (a) four threads from each year (where possible); (b) a diversity of subjects and topics related to ventilation or airway management; and (c) threads of a variable length. The first data corpora were used to develop the data dictionary and coding schema, with the second used for inter-rater reliability.

3.5 | Ethics

The Human Research Ethics Committee at the University of Technology Sydney approved the study as a "Low/ Negligible Risk" project (HREC 2010-364A-1), given that retrospective data were used, and VC member identification was removed. Community members were informed of the research through an online post asking for discussion, noting that issues of privacy and confidentiality were consistently maintained. Data were stored securely within a university-specific cloud server with access limited to the research team.

3.6 | Data analysis

Summative content analysis (Hsieh & Shannon, 2005; Zhang & Wildemuth, 2009) was used to understand the content and

TABLE 2 Keyword search

Ventilation	Airway
Ventilation	Intubation
Invasive	Extubation
CPAP	endotracheal tube
BiPAP	tracheostomy/tube
Mask	Trache
Non-invasive	Humidification
Mode	

context of discussions. This allowed the exploration of both manifest and latent content of textual data within the practice context (Colorafi & Evans, 2016). Manifest content (categorical variables) of emails included: (a) Parent (post which starts the thread) or child (replies); (b) major and minor subject and topics; (c) poster demographics; and (d) knowledge type. Variables concerning the demographics of posters included: (a) HCP group (nurse, physician, allied health, healthcare management and industry); (b) member type; and (c) unit type. Nursing type was further categorised according to role in ward or facility including: (a) nursing unit manager (NUM) Nursing manager; (b) knowledge broker (nurses in educator or research roles); (c) Nurses who provided direct clinical care either within the ICU (bedside clinical nurse or across more than one ward (cross-unit clinical nurse); or (d) Nurses employed at a university (academic nurse). Knowledge types were based on those listed in Table 1.

Manifest variables are described using frequencies and proportions. Inter-rater reliability of knowledge type was evaluated using Cohen's kappa [κ] as there were two independent coders, data were nominal, and cross-tabulation was symmetrical. An agreement of greater than 0.75 indicated excellent agreement, between 0.74–0.4 was considered good agreement, while less than 0.40 was considered poor (McHugh, 2012). In NVivo, matrix queries assisted identification of patterns between nodes and potential differences across member types. Tables were created to compare responses from different member types or cross-node comparison.

3.7 | Procedure

The study was conducted over seven stages (Zhang & Wildemuth, 2009):

1. The sampling process is described previously. Once a discussion thread was identified, it was pasted into a MS Word document (Microsoft Corporation), given a unique code and de-identified. An excel workbook (Microsoft Excel) was used to manage this.
2. Individual emails were treated as the unit of analysis, with the complete discussion thread the contextual unit. This was in keeping with the pragmatic approach and provided context to the discussion thread (Colorafi & Evans, 2016) and added credibility to data interpretation.
3. Four threads from were examined to develop an understanding of the texts, with manifest (knowledge type, subjects and topics, and poster demographics) and latent (context of knowledge exchange) content coded inductively in NVivo (QRS International, Melbourne Australia). The remaining 16 threads (of data corpora 1) were coded using a standardised approach. During this process, a data dictionary (see multimedia Appendix S1) was developed iteratively to reflect categories and process. Categories for knowledge type data were added to the worksheet.

4. Evaluation of inter-coder reliability was undertaken with 25% of sample (seven threads; 43 emails) coded by an independent coder to test the knowledge types in the data dictionary. The coder had extensive intensive care experience and understanding of knowledge management and was provided with four hours of training. Data were entered into SPSS (Statistical Package for Social Sciences; PASW Statistics for Windows, version 18.0, 2009. SPSS Inc.). The final coding schema was revised based on outcomes from this process.

5. Coding of the second data corpora was undertaken, with deductive coding of manifest data entered on the worksheet while coding of latent content continued using NVivo. The second round of inter-coder agreement was completed on 22% of data corpus two (five threads; 33 emails). This stage completed coding for manifest data.

6. A constant comparative approach enabled refinement of nodes and development of tree nodes or master categories for the latent content.

7. Classification sheets were developed and imported into NVivo to support data analysis. For further information refer to File S2

4 | Findings

A description and analysis of the manifest content of the data corpus will be reported first, including a description of the discussion threads and member's posting behaviour, the subjects and topics discussed, and knowledge types exchanged. Second, analysis of the latent content revealed a novel construct "virtual community work" as an explanation of members' contributions to ICUConnect. Lastly, two themes that emerged connecting the VC to the broader intensive care community: the "complexity of clinical practice" and "loss of corporate memory," will be discussed. Where appropriate, quotes from discussion threads are used to elaborate the findings, and related references are cited to provide context. The data dictionary (multimedia Appendix S1) and an exemplar thread (multimedia Table S1) are provided as supplementary material for context.

4.1 | Analysis of manifest content

4.1.1 | Description of discussion threads

The sample consisted of 326 emails across the 40 discussion threads (emails per thread median 6; IQR 5–10), with contributions from 133 members (posts: mode 1, median 1, maximum 55) across 80 organisations—67 hospitals (posts: 86%; n = 280), five health departments (posts: 10%; n = 33), six universities (posts: 3%; n = 6) and two healthcare companies (posts: 1%; n = 2). For each thread, the most frequent number of members interacting was five (median 6 [IQR 4.75–7]). A majority of contributions came from a minority of members: 72% (n = 235) were from 40 members

who posted more than once, while 50% (n = 164) were from the ten members who posted more than five times (range 5–55; see Table 3). Intensive care nurses contributed most, initiating 33 threads and providing 64.7% of the replies, whereas physicians initiated 12.5% (n = 5) of the discussions and contributed to 29% of replies. Table 4 illustrates the differences in how the various professional groups and member types contributed to discussion threads.

Three major subject areas were identified and were further categorised into eleven minor subject areas covering 28 primary topics (see Table 5). "Clinical procedures" was the largest minor topic area (14 threads) covering almost 50% of all data. Members requested information regarding artificial airways (primary topic) and included queries regarding secondary topics such as tracheostomy care (five threads), securement of an endotracheal tube (four threads) and suctioning (three threads). As an illustrative example, Figure 2 shows the inter-related sub-topics covered in threads related to endotracheal tube securement. Also, evident was that members asked questions and contributed to threads according to their job role and scope of practice (see Figure 3). This was reflected in clinical leaders, including nursing unit managers (NUM), knowledge broker (KB) nurses, ICU directors and staff specialists (physicians), who contributed to threads across all subject areas, while bedside nurses focused on clinical practices (see Figure 3).

4.1.2 | Knowledge exchanged

Knowledge type coding identified 21 different types in the data: explicit (n = 9); experiential (n = 9); know-how; know-why; and clinical advice. Significant inter-coder agreement was achieved across:

- All data (Cohen's kappa [κ] = 0.795; p = .000; 95% CI 0.71–0.87.
- Data corpora 1 κ = 0.695; p = .000; 95% CI 0.611–0.849.
- Data corpora 2 κ = 0.711; p = .000; 95% CI 0.757–0.950).

The knowledge types were then collapsed into six categories (see Table 6; for further information and exemplars of knowledge types, see —File S3 data dictionary).

It was commonly noted that the initial poster requested both explicit and experiential knowledge, usually regarding product availability and other members' experiences. For example, "Does anyone

TABLE 3 Data corpus distribution

Posts' frequency (grouped)	Number of members	Posts % (n)
1	92	27.91 (91)
2–4	30	21.78 (71)
5–9	4	7.67 (25)
10–19	4	18.40 (60)
>20	2	24.23 (79)
	133	100 (326)

TABLE 4 Contributions to discussion threads by member types

Type of member	% (n=)	Total emails - % (n=)	Parent[†] % (n=)	Child [†] - % (n=)
Nurse	75.9 (101)	66.9 (218)	82.5 (33)	64.7 (185)
Knowledge broker [‡]	34.6 (46)	39.6 (129)	32.5 (13)	40.6 (116)
Nursing unit manager (NUM) [§]	14.3 (19)	13.2 (43)	20.0 (8)	12.2 (35)
Bedside clinical nurse	15.8 (21)	7.7 (25)	27.5 (11)	4.9 (14)
Cross unit clinical nurse	6.0 (8)	3.4 (11)	2.5 (1)	3.5 (10)
Academic nurse	3.8 (5)	2.5 (8)	0	2.8 (8)
Nurse manager	1.5 (2)	0.6 (2)	0	0.7 (2)
Physician	14.3 (19)	27 (88)	12.5 (5)	29 (83)
ICU specialist [¶]	6.0 (8)	19.6 (64)	10.0 (4)	21.0 (60)
ICU director[¶¶]	8.3	7.4	2.5	8.0
Allied health	4.5 (6)	3.1 (10)		3.5 (10)
Speech pathologist	4.5 (6)	3.1 (10)		3.5 (10)
Healthcare management	3 (4)	1.8 (6)	2.5 (1)	1.7 (5)
Facility management	2.3 (3)	0.9 (3)	2.5 (1)	0.7 (1)
Healthcare manager	0.8 (3)	0.9 (3)		1.0 (3)
Industry	1.5 (2)	0.9 (3)		1.0 (3)
Unknown member	0.8 (1)	0.3 (1)	2.5 (1)	
	(133)	(326)	(40)	(286)

[†] Parent refers to email which starts discussion thread whereas Child refers to subsequent replies in discussion thread

[‡] Knowledge broker nurses are in research and education roles; 2 members responsible for 34.5% of all posts; 7 posted > 2; 10 members posted twice; 30 members posted once only

[§] One NUM was responsible for 38.7% of emails from this member type

[¶] One specialist posted 55 times; equals 16.8% of all emails; equals 85.9% for this member type; 2 members posted twice; 5 posted once only

[¶¶] One ICU director posted 11 times; equals 45.8% for this member type; 2 posted ≥ 2; 8 posted once only

have any information on any portable End Tidal CO_2 equipment which is available? Good experiences etc; which we may find useful in determining the best product available." According to knowledge requested, different job roles had different knowledge needs that reflected their scopes of practice. For example, when requesting knowledge, enquiries from members who were in NUM roles were mostly about availability and experience with a product or service, while bedside nurses were more concerned with institutional practice experiences. In contrast, KB nurses requested all knowledge types, but asked for explicit knowledge more often (9/13 requests). It was also noted that there were no breaches of patient confidentiality or privacy across any of the 40 threads (refer to File S4 exemplar thread).

4.2 | Analysis of latent content

The central construct of virtual community work emerged from the latent content along with themes linking ICUConnect to the broader intensive care world (see Figure 4).

4.2.1 | Virtual community work

The construct of "virtual community work" emerged during refinement of final themes over the latter stages of data analysis. Virtual community work reflected any direct or indirect actions undertaken by members that contributed to creating a safe online space where VC members could trust that their questions would be received and answered in a collegial professional atmosphere. Six elements

were identified: (a) the discussion thread; (b) sharing of artefacts; (c) community; (d) cordiality; (e) maven work; and (f) promotion of the VC (see Figure 4). While the discussion thread is the most visible component of virtual community work, the latter five components create a safe collegial environment or a positive social environment that facilitates knowledge exchange and development of the VCoP knowledge base (Barnett et al., 2012).

Discussion thread

Posting within a discussion thread was the most direct action or work of VC members, with three major sub-elements noted: the request for and supply of knowledge (described earlier), and the purpose and concerns that motivated a member to post.

Purpose of post. The purpose for all *parent* or first posts was to "benchmark" practice, while answers/replies were distributed between answering a question and promoting discourse (see Figure 4). For this data set on mechanical ventilation or airway management posts, members were interested in benchmarking across five areas: procedures (*n* = 17 posts), equipment (*n* = 19), clinical decision-making (*n* = 6), education (*n* = 1) and staffing (*n* = 1). These differences are illustrated in Exemplar 1. Three purposes were noted for members responding to an original post: (a) providing an answer; (b) promoting discourse; or, rarely, (c) thread thwacking (introduction of a new unrelated topic). "Providing an answer" was usually multi-dimensional and included descriptors of local practice, equipment or product use, description of the evidence base, provision of information, clinical advice and/or supply of local resources such as guidelines and education packages. "Promoting

TABLE 5 Major and minor subject areas

Major subject - Minor subject	Threads n=	% (n= posts)
Clinical practices	**25**	**70.55 (230)**
Procedures	14	49 (159)
Ventilation management	5	9 (30)
Infection Prevention	2	6 (21)
Assessment and Monitoring	2	3.37 (11)
Respiratory support	1	2 (5)
Drug protocol	1	1 (4)
Equipment	**12**	**23.01 (75)**
Airway - artificial	4	8.0 (26)
Ventilation circuit	5	9.5 (31)
Ventilator	3	5.5 (18)
Clinical governance	**3**	**6.44 (21)**
Risk management	2	5.52 (18)
Staffing	1	0.92 (3)
	40	100 (326)
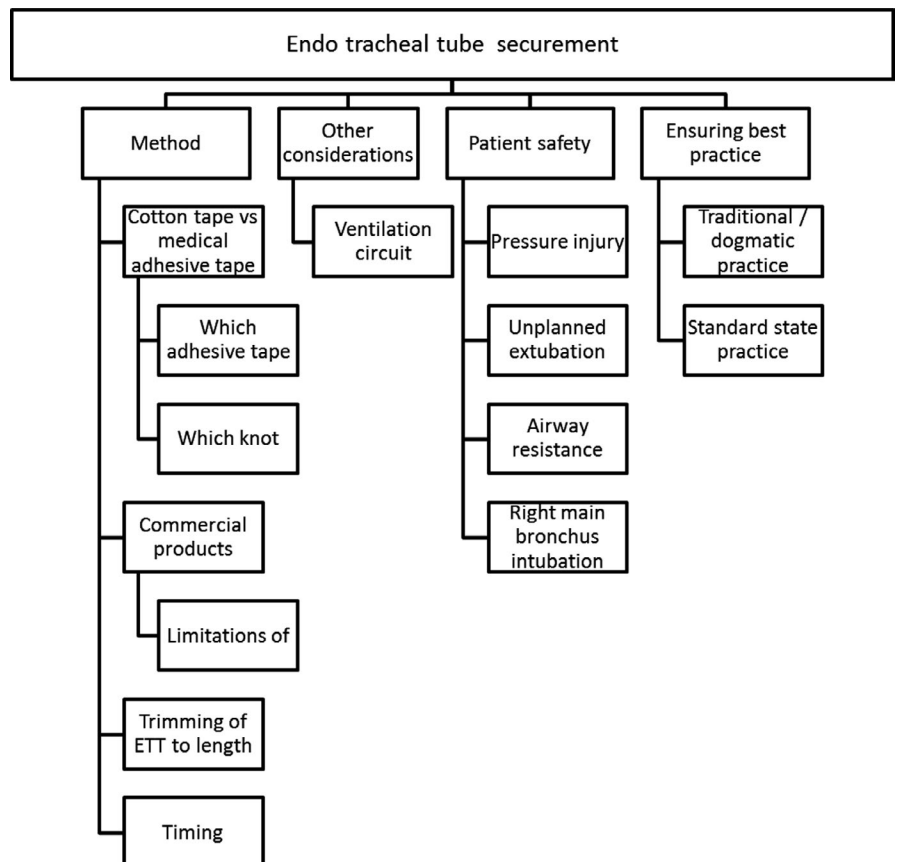
FIGURE 2 Topics covered in discussion on endotracheal tube securement
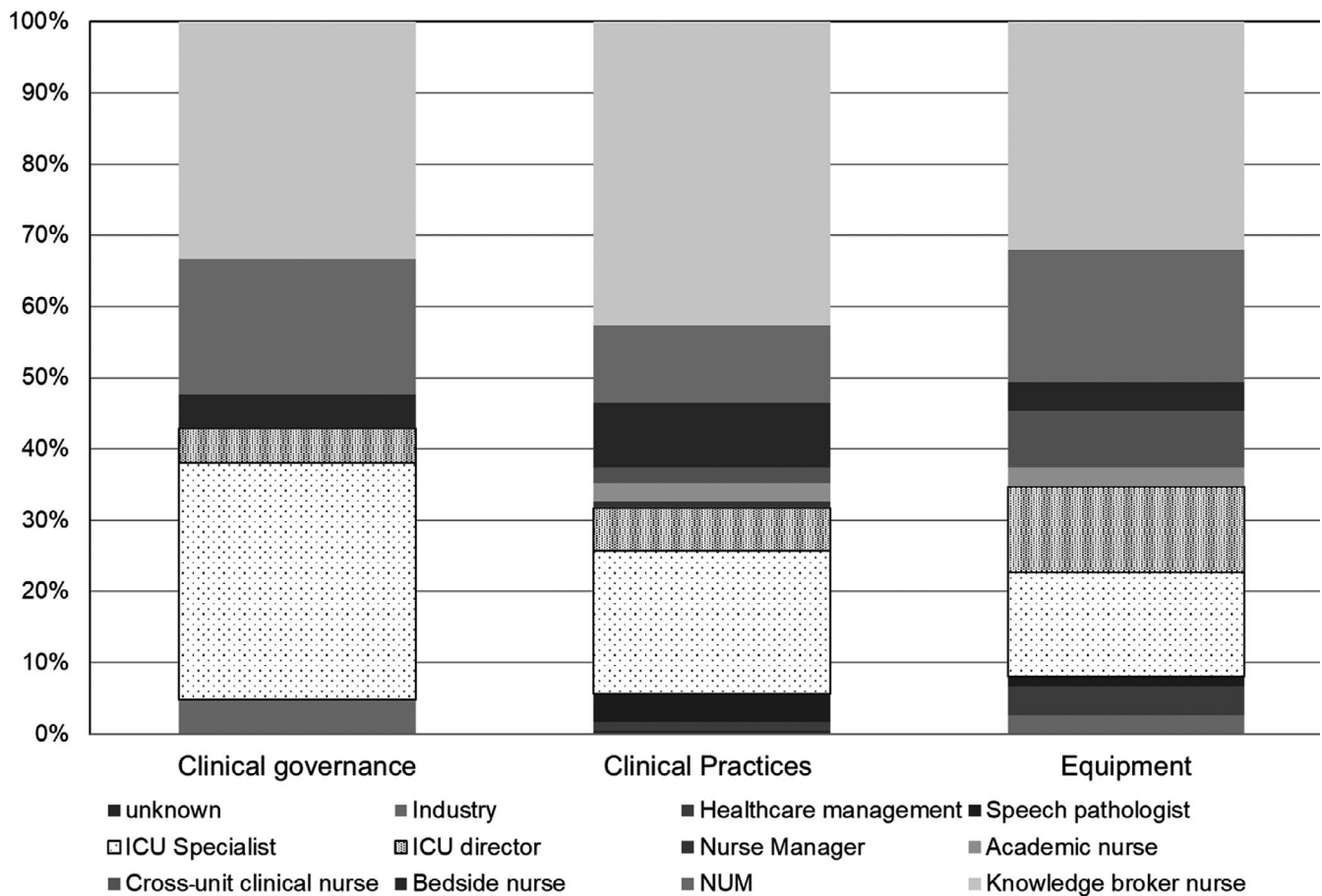
Subject area contributions by member type

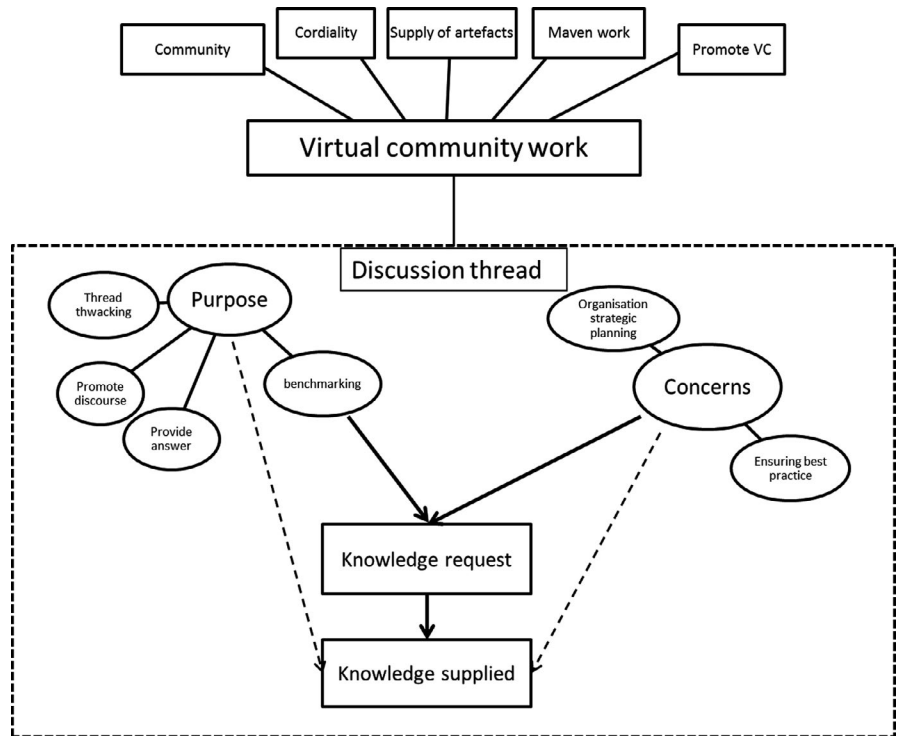**FIGURE 3** Subject area contributions by member type

TABLE 6 Knowledge types identified in online discussions

Knowledge categories	Requested % of whole data set (n)	Supplied % of whole data set (n)
Experiential + explicit	33.3 (21)	16.6 (43)
Experiential	27.0 (17)	35.4 (93)
Explicit (i.e., guidelines or research)	39.7 (25)	17.1 (45)
Know-how (problem + solution/s with detail + rationale/s)	n/a	19.8 (52)
Know-why (problem + solution/s + rationale/s + evidence + situational application + reflection)	n/a	5.3 (14)
No knowledge	n/a	6.1 (16)

discourse" was the most common sub-purpose (with responses primarily from physicians, KB nurses and NUMs). These posts were characterised by either: "agreement with," "challenge to," "clarification," "broadening the discussion" through addition of other related issues or "summary of the discussion" to that point in the thread. Promoting discourse underscores the value of online discussions in drawing attention to the complexity and dynamic nature of clinical practice, and then to balance multiple aspects of care (see Figure 2).

Concerns. Posts reflected one or more concerns, issues or potential problems related to mechanical ventilation or airway management discussion threads. The dominant concern was "ensuring best practice," reflecting a core value of the speciality and the VC. Conversely, organisational 'strategic planning' was described only once. Nurses in bridging roles (KB nurses and nurses who worked across multiple units) and physicians had concerns covering the whole practice spectrum, while NUMs were concerned with product company recommendations and organisational strategic planning.

FIGURE 4 Virtual community work

Exemplar 1 Purpose—benchmark practice[102]

Type of member	Area	Quote
NUM	Equipment (*n* = 9)	"Does anyone have any information on any portable End Tidal CO_2 equipment which is available, good experiences etc; which we may find useful in determining the best product available."
Knowledge Broker nurse	Procedures (*n* = 7)	"In terms of infection prevention—how often do disposable BVM resuscitators get changed—do people practice daily changing of bags that have been opened for intubated and ventilated patients OR do they use them for the whole duration of admission OR is it a weekly change."
Clinical nurses	Procedures (*n* = 7)	"I am interested in what methods other units use to prevent patients developing pressure areas from et tapes, particularly the corner of the mouth."
Physicians	Clinical decision-making (*n* = 3)	"I am interested to learn what is considered to be the best practice for oxygen delivery prior to ETT suction."
Facility management	Equipment (*n* = 1)	"I am interested to hear what the current trends are with the use of Inline suction systems."
Speech pathologist	Clinical decision-making (*n* = 1)	"Does anyone 'out there' have any good evidence re patients with tracheostomies having ice to suck."

\# This table provides an example of the most common question group asked by each member type NB some responses have been shortened.

Ensuring best practice had several elements. The most common was "prevention of adverse events," which often included warnings of possible unintended negative consequences of a practice and other concerns related to scope of practice. For "balancing the evidence," posters usually listed at least two issues for consideration prior to making a clinical practice decision (e.g., does the contamination of a Yankauer sucker lead to actual cross-contamination and infection?). "Improving patient outcomes" was concerned with direct improvement in a patient's condition (e.g., reducing length of ventilation or effective discharge of a ventilated patient to home). "Compliance with state or national professional standards" was viewed as important by some members. Company recommendations for appropriate product use were also a common concern. Here, posters were troubled by what were the appropriate recommendations, the research basis supporting these recommendations and the consequences of noncompliance. A "lack of research" evidence was commonly noted when posters described barriers to ensuring best practice, followed by staff compliance with evidence-based recommendations, failure to evolve practice, organisational barriers and difficulties in describing best practice. This "lack of research" concern may have been a reflection of the frequent topic of ETT or tracheostomy securement where the evidence base is limited (Rolls & Elliott, 2008).

Creating a safe collegial environment

A safe collegial environment was created by the synergism between the five remaining elements including: (a) community; (b) cordiality; (c) supply of artefacts; (d) maven work; and (e) promotion of the VC. The "community" was created by a shared reality for members and established by two sub-elements of "homophily" and "temporality of issues." Homophily was illustrated through comments such as "back to the grind" or "Hi troops," which reinforced that members shared similar goals, values and experiences (Rogers, 2003). "Temporality of issues" was revealed as members "admitted" they too were presently grappling with similar problems as an original poster, as illustrated in Exemplar 2.

Cordiality creates the necessary supportive and professional social atmosphere that sustains online participation and is comprised of four characteristics: (a) salutations (noted in n = 71 posts); (b) humour (n = 26); (c) sarcasm (n = 4); and (d) discussion of VC rules (n = 3). Salutations, seen at both the opening and closing of posts, were common, lending a polite and collegial tone to discussions. Humour was used more commonly than sarcasm in this data set; for example, "Off the horse and back to work!!! No shares in JCN guidelines." These textual elements served to reduce any tension and add informality to discussions, promoting the necessary camaraderie in an online forum. The use of emoticons was uncommon although this may have been a function of using software that limited functions to standard keyboard keystrokes.

Virtual community etiquette and rules were illustrated by the following comment, "FYI in general we shouldn't post PDFs onlist UNLESS they are freely available and this one was." Significantly, despite the high level of replies focusing on promoting discourse and the use of sarcasm, discussions were managed collectively in

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> **Exemplar 2 Temporality of issues**
>
> **'In response to a post regarding use of non-invasive ventilation mode on ventilators predominantly used for invasive ventilation …**
> 'Interesting thread as we are currently looking at new ventilators here at H-9 AICU. In our consensus meeting we did not feel that any of the "invasive" vents [mechanical ventilators] performed as well as the Brand X (we own 5), hence it is not one of our major criteria to evaluate ventilators. We agreed conceptually that it would be great if invasive vents performed well in NIV.'
> **In response to a post on nurse-patient ratio for patients receiving non-invasive ventilation**
> I would be interested in responses to the list.

a professional manner with no hostile or insulting posts (flaming or trolling) noted; rather, interactions reflected those observed at professional conferences.

The remaining components of virtual community work (see Figure 4), including "sharing artefacts," "maven work" and "VC promotion," worked together to highlight the value members were able to find in the VC. Artefact sharing (n = 41) included posting of resources (e.g., clinical practice guidelines, reports, articles, images or URLs linking members to online resources such as videos). Maven work (posting by key members who take the time to provide complex lengthy answers) was coded as know-why knowledge. Virtual community promotion is exemplified by the following quote; "Thanks for the advice on the CPAP/ BiPAP last week, M-59 (a maven). The educators say thanks, our shout." Inclusion of direct thanks for knowledge received reinforces to members that the VC is an important source for key information and knowledge.

4.2.2 | Broader intensive care context

Two important themes emerged that linked ICUConnect to the broader intensive care practice context: the "complexity of clinical practice" and "loss of corporate memory." The complexity of clinical practice was illustrated by numerous threads that unpacked nuances of clinical practice in three key ways: (a) through the types of knowledge displayed; (b) introduction of related topics; and (c) the purpose of promoting discourse. This reinforced to members how multi-dimensional intensive care practice is and, importantly, how it changes over time (see Figure 2).

The loss of corporate memory with an ICU emerged as discussions evolved concerning three clinical practices for which the original theoretical, scientific or safety rationale was no longer valid (see Table 7). The most conspicuous example was two threads posted in 2010 concerning the routine deflation of tracheostomy cuffs to prevent tracheal necrosis, a clinical practice not required since the

TABLE 7 Discussion thread topics illustrating loss of corporate memory

Year of discussion	Topic
2005	ETT securement with reference to routine trimming of tube in pre-hospital setting (Patel, Mahajan, & Ellis, 1993)
2006	Routine manual hyperventilation to prevent hypoxia secondary to airway suction (Woodgate & Flenady, 2001)
2010	Routine deflation of tracheostomy cuff to prevent tracheal necrosis (Haas et al., 2014)

1980s, when low-pressure high-volume cuffs replaced high-pressure low-volume cuffs on tracheal tubes (Haas, Eakin, Konkle, & Blank, 2014). Critically, the discussions that developed indicated not only were these practices no longer required, they were also potentially dangerous for patients.

5 | DISCUSSION

This study explored the nature of knowledge exchange on an exemplar VC, ICUConnect, using summative content analyses methods, enabling evaluation of both the content and context of online discussions. The key finding was that the "virtual community work" undertaken by members established a safe collegial online culture that facilitated the exchange of essential clinical knowledge, promoted the professional development of members and encouraged innovation diffusion within a clinical speciality.

5.1 | An emergent virtual community of practice

A case for ICUConnect as a VCoP emerged, with study findings supporting presence of five of seven essential characteristics (see Figure 1). Two important characteristics of a VCoP are access to high-quality domain-specific content, with direct practical application to everyday practice, that was provided by a diverse range of members (Barnett et al., 2012; Chang et al., 2014). Analysis of discussions over ten years demonstrated that ICUConnect discussions consistently provided members with access to relevant practical and valuable knowledge, especially know-how and know-why knowledge. This study reaffirmed previous research, that is the exchange of domain-specific experiential knowledge commonly occurred between a minority of members (Rolls et al., 2016b). The finding that a majority of online posts were from a minority of members is also consistent with previous research examining online participation, either directly via online observation (Morken et al., 2009; Rodriguez-Recio & Sendra-Portero, 2007; Stewart & Abidi, 2012) or indirectly via surveys (Rolls et al., 2008). This suggests the presence of a critical mass of experienced and expert members have developed vital community norms, thus ensuring the availability of high-quality content (Antonacci et al., 2017; Barnett et al.,

2012; Chang et al., 2014). These online practice norms include altruism, reciprocity, social interaction, knowledge sharing and trust (Antonacci et al., 2017; Kurtz-Rossi, Rikard, & Mckinney, 2017).

There were two novel and important results. Participation included most member types of the MDT from many locations, representing significant structural and professional boundary spanning across the Australasian intensive care community. A high rate of IC leader participation was also noted. These findings demonstrate a strong willingness to communicate with professional colleagues to obtain new knowledge and share their knowledge, and to compare local practices with colleagues. It is also unlikely that ICUConnect operated as an echo chamber, as knowledge was contributed by clinical leaders from 80 facilities throughout Australasia, demonstrating effective boundary crossing and providing access to alternate knowledge and perspectives (Kothari et al., 2011). Types of knowledge exchanged were, in part, driven by the knowledge requested by the member posting the original thread, thus providing an explanation for the high levels of experiential knowledge identified previously (Abrahamson et al., 2013). To our knowledge, this is the first study to develop a theoretically driven knowledge taxonomy, with strong inter-rater reliability, that effectively linked the VCoP to the real world of clinical practice, especially know-why knowledge as an expression of clinical expertise and evidence-based practice.

The elements of virtual community work, the discussion thread and creation of a safe collegial environment, demonstrated that ICUConnect developed several more elements of a successful VCoP. The dialogical interactions within the discussion thread illustrated how members were able to reach out to colleagues for key knowledge, to vicariously experience innovations and importantly gain varying perspectives on practice; this emphasises the social construction of knowledge in health (Murad et al., 2017). This is illustrated by the finding that the primary reason for members requesting help was to compare or benchmark local practices, previously noted as an essential benefit of VC membership (Kurtz-Rossi et al., 2017; Trinacty et al., 2014).

This discussion thread model illustrated collective knowledge creation, as various VC members worked together to solve a knowledge need or local problem presented by the first poster. These conversations, discussions and potential difference of opinion that occur online are a key attribute of a VCoP (Barnett et al., 2012; Chang et al., 2014), enabling development of professional knowledge for individual members and the collective practice knowledge of the community, leading to potential improvements in practice and innovation (Kurtz-Rossi et al., 2017; Trinacty et al., 2014; Wenger, 2004).

Members created the necessary VCoP element of a respectful risk-free online environment where participation is possible without negative consequences (Barnett et al., 2012; Chang et al., 2014). Critically, knowledge exchanges were cordial and professional, reinforcing acceptable online behaviours to all members, and especially to new members. Collegial disagreement is a critical characteristic of online discussions as it promotes participation and retention of members (Trinacty et al., 2014), Role modelling of appropriate

intra- and inter-professional communications also facilitates development of a shared understanding of knowledge and roles within the multi-disciplinary team (Dias & Escoval, 2015).

5.2 | Virtual communities of practice mobilise knowledge and distribute innovation across a healthcare organisation

The potential for a multi-disciplinary VC to facilitate knowledge and clinical expertise exchange within professional networks and across organisations was demonstrated in these findings and supported by others (Currie & White, 2012; McGowan, 2012; Morken et al., 2009). ICUConnect established crucial weak ties and social network interconnectedness critical for exchange of best practice knowledge across a healthcare system (Antonacci et al., 2017; Rogers, 2003). High levels of participation by clinical leaders and experts were important for two reasons: a VCoP will continue to grow where there is valuable content contributed by community leaders (Antonacci et al., 2017) and demonstrates an external orientation required of organisational leaders for novel knowledge to be integrated into organisational practices (Greenhalgh, Robert, Bate, MacFarlane, & Kyriakidou, 2005). Benchmarking practice facilitates knowledge mobilisation and distribution as peer-to-peer recommendations are highly influential on innovation uptake and practice change (Greenhalgh et al., 2005; Rogers, 2003). Further, the content of conversations between professional colleagues identifies what clinical practices are important and of particular concern for a professional community (Duncan et al., 2014).

Furthermore, as previously noted the VC is not an echo chamber as demonstrated by the challenges to the veracity of VC posts and stands in stark contrast to transfer of knowledge in a ward setting where clinicians may not question what they have been directly told (Marshall et al., 2011). The failure of HCPs and organisations to cease using or investing in outdated, unsafe or non-evidence-based practices, which potentially contribute to poorer patient outcomes (Hollingsworth et al., 2015) is of significant concern in health care (Braithwaite & Donaldson, 2016). This issue was illustrated by the theme "corporate memory loss"; if clinicians do not have communication channels beyond local social networks, they may be under the illusion that local practices reflect the majority view (Duncan et al., 2014) and fail to evolve practices. These practices may continue to linger when key individuals leave, further reinforcing clinical practice silos created by ineffective social networks where units are not connected to the broader professional organisation and HCPs do not engage with their professional community. Failure to incorporate emergent knowledge into practice therefore places organisations at risk of not delivering best practice, while the haphazard incorporation of new evidence and diffusion of innovative practices continues to negatively impact on the quality and safety of healthcare delivery (Braithwaite & Donaldson, 2016). Online behaviour in ICUConnect therefore addressed the risks of group think and homophily that may be present in limited social networks where questioning local

practices can be difficult despite having strong contrary evidence (Rycroft-Malone et al., 2013).

5.3 | Participation of nursing leaders in multi-disciplinary speciality-specific VCoPs

Participation in multi-disciplinary speciality-specific VCoPs facilitates the professional development of nurses, provides clinical leaders with valuable knowledge for application in local settings and enhances the unique contribution of nurses to patient care (Adams et al., 2015). Patient care provided by expert clinical nurses is a fundamental component of quality care (Manley et al., 2005), and access to this expertise is important as evidence underpinning many nurse practices is limited (Rolls & Elliott, 2008) and compounded by an increasingly limited supply due to ageing workforce (Cioffi, 2012). Moreover, expertise includes both mastery of a specific knowledge and practice domain, and the ability to cross-boundaries and participate in other communities (Kothari et al., 2011). Membership of a VCoP therefore provides nurses with professional development opportunities and access to valuable clinical knowledge. Importantly, this present study demonstrated the willingness of nursing leaders to actively engage in professional discourse, demonstrating that nurses are not passive knowledge consumers.

5.4 | Methodological Strengths and Limitations

Key design decisions addressed limitations of previous studies so that a clear and comprehensive exploration of knowledge exchange on ICUConnect was possible. Trustworthiness was established by describing a clear audit trail and providing a thick description of the research process, including procedural steps and members involved in online discussions. The robustness of the process for developing the knowledge categories was demonstrated, with categories based on theory and application of the data dictionary to two substantial data sets.

While the sampling plan gathered a substantial data set for a considerable time, the purposive approach limits generalisability of findings to other areas of clinical practice. The focus on ventilation and airway management may have therefore restricted responses to those with needs or expertise in this specific clinical practice and may also have limited participation from some allied health professionals or managers. A random or census sample would have gathered discussion threads more reflective of the scope of these online discussions; however, this was not possible with the archival arrangements of the VC at the time of the study.

Use of discussion threads with three or more posts may present an overly positive view of discussions and knowledge exchange. Members who posted in these discussion threads may therefore not be reflective of the general membership, and this may be compounded by an inability to complete a comparison against general

membership because a contemporary demographic evaluation was not possible. In addition, without a survey of all members or social analysis techniques, findings regarding an online environment conducive to participation should be considered preliminary. Note, however, that the exploratory nature of this study did not require a representative sample of threads or members.

A key strength was the use of summative content analyses, enabling identification of both knowledge exchanged and the context within which this exchange occurred. This facilitated development of a novel construct virtual community work model, enabling more clarity about why members posted, and the social context of the VC in supporting participation and knowledge exchange. Maintaining the unit of analysis within its contextual unit provided an explanation for the high rate of experiential knowledge exchange on nursing VCs, a previous criticism of these communities (Abrahamson et al., 2013). An acceptable inter-rater reliability was achieved for categorising knowledge types, a crucial element missing from other HCP VC studies (Rolls et al., 2016b).

Lastly, because ICUConnect was established in 2003 using listserv technology, it is important to consider how viable or relevant this platform is within the increasingly complex and evolving contemporary social media landscape. At the time of this study, ICUConnect was based on the original form of mailing lists; posts went directly to the email boxes of members. At this time, listserv platforms are still being used by several HCP VCs. MEDLIB, a community for medical librarians established in 1991, continues to use a listserv platform and was rated higher than other social media by members (Muñoz-Cañavate, Fernández-Falero, & Hurtado-Guapo, 2017b). The ongoing relevance of the platform is also seen in the continuing use of the RedIRIS communities by Spanish HCPs (Muñoz-Cañavate, Fernández-Falero, & Hurtado-Guapo, 2017a), the health literacy discussion list (HLDL; Kurtz-Rossi et al., 2017) and the "Implementation and Optimization Forum" created in 2012 by American Medical Informatics Association (AMIA).

6 | CONCLUSION

This study evaluated whether a multi-disciplinary VC for Australasian intensive care HCPs facilitated knowledge and clinical expertise exchange. The study builds on the contemporary evidence base on professional VCs in several key areas. "Virtual community work" was identified as the mechanism that drives a successful VCoP. The work of a small number of VC leaders drives the exchange of high-quality domain-specific knowledge, validating member participation especially those in leadership roles. Lastly, the viability of social media platforms, in this case a listserv, to support development of a practice-based VCoP is confirmed.

7 | RELEVANCE TO CLINICAL PRACTICE

This study demonstrated that a practice-based VC can function effectively as a VCoP to establish an effective professional

network where members have access to up-to-date best practice knowledge. Healthcare organisations could leverage VCs to support the professional development of HCPs and ensure that local clinical practices are based on contemporaneous knowledge. Participation by nurses in these communities facilitates individual professional development and access to important clinical knowledge and expertise, and ultimately reinforcing the unique position of nursing in delivering effective, consistent high-quality patient care.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.