POINT-OF-CARE ULTRASOUND EDUCATION NEEDS FOR NURSE PRACTITIONERS IN PRIMARY CARE SETTINGS: AN INTEGRATIVE REVIEW

by

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ABSTRACT

Point-of-care ultrasonography (POCUS) is the process of operating a compact ultrasound machine at a patient's location and immediately integrating the images generated into patient care. POCUS can help nurse practitioners (NPs) make more accurate diagnoses, facilitate safer procedures, and bridge health care access gaps in resource-limited settings such as primary care; however, it is widely agreed that POCUS is operator-dependent and that appropriate education is required to competently operate the device. This integrative review sought to determine what education NPs need to competently operate POCUS in primary care and it was found that there is no data specific to NPs; much of the available information is instead within the medical literature. Given the numerous benefits of POCUS for improving patient care and health care systems efficiency, NPs must urgently determine their POCUS education needs as they have ethical and legal obligations, in addition to a professional responsibility to ensure safe, high-quality patient care.

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GLOSSARY OF TERMS

Competence: the integration of knowledge, skills, judgement, and attributes that are required to practice safely and ethically in a designated role and a specific setting (Canadian Nurses Association [CNA], 2010).

Competency: specific knowledge, skills, and personal attributes required to practice safely and ethically in a designated role and a specific setting (CNA, 2010).

Confidence interval (CI): range of values within which the true value is expected to exist (Davies & Logan, 2018); quantifies the precision of a given test result.

Consultative ultrasonography: traditional process of ultrasonography acquired by ordering the test, which is then performed by a technician, after which the results are interpreted by a radiologist who is often not present at the point of care and/or not directly involved in the patient's care (Díaz-Gómez et al., 2021); also known as traditional ultrasonography.

Credentialing: "identifies the kind of medical procedures and services a practitioner is qualified for and assesses a practitioner's education, experience, training, and past and current history of practice. Credentialing informs privileging" (British Columbia Medical Quality Initiative [BCMQI], 2018, p. 1).

False negative: negative test result for the disease in question, but the patient has the disease (Bickley et al., 2021).

False positive: positive test result for the disease in question, but the patient does not have the disease (Bickley et al., 2021).

Graduate education: education beyond the baccalaureate level, including master's, doctoral, and postdoctoral studies (CNA, 2019).

Kappa (k) statistic: a test that determines the level of agreement beyond chance (Davie & Logan, 2018).

Licensing: granting of permission to hold registration within a regulatory college body (BCMQI, 2018).

Negative likelihood ratio: ratio of the false-negative rate to the true-negative rate; a lower negative likelihood ratio indicates that the test results are a stronger negative predictor that a person with a negative result does not have the disease in question (Bickley et al., 2021; Worster et al., 2021).

Negative predictive value: probability that a patient with a negative test result has the disease (Bickley et al., 2021).

Point-of-care: the patient's location where health care services are provided.

Point-of-care ultrasonography: acquisition, interpretation, and immediate clinical integration of ultrasonographic imaging performed by a treating clinician at the patient's location (Díaz-Gómez, 2021; Moore & Copel, 2011).

Positive likelihood ratio: ratio of the true-positive rate to the false-positive rate; a higher positive likelihood ratio indicates that the test results are a stronger predictor that a person with a positive result has the disease in question (Bickley et al., 2021; Worster et al., 2003).

Positive predictive value: probability that a patient with a positive test has the disease (Bickley et al., 2021).

Post-test probability: probability that the disease in question exists after accounting for all test results (Bickley et al., 2021).

Pre-test probability: probability that the disease in question exists before any test is performed; also known as prevalence (Worster et al., 2002).

Primary care: provision of health care services that is first-contact, accessible, continuous, comprehensive, and person-centred (World Health Organization [WHO], n.d.-a). Examples include vaccination, health promotion, and disease prevention.

Primary health care: approach to health that involves all levels of society, including health services such as primary care, multi-sectoral policies to address the determinants of health, and the engagement of individuals and their communities to ensure the highest level of health and the equitable distribution of health promotion and disease prevention (WHO, n.d.-b).

Privileges: site-specific permissions to practice clinical activities (BCMQI, 2018).

Privileging: process of granting facility-specific privileges to practice clinical activities (BCMQI, 2018).

Regulation: where a profession and its members are determined, the scope of practice is defined, education and ethical standards are set, and accountability is established (Styles & Affara, 1997, as cited in CNA, 2019).

Scope of practice: activities that a professional is educated and authorized to perform, as defined by their respective legislation and any standards set by their regulatory college (CNA, 2019).

Sensitivity: ability of a diagnostic test to detect who has the disease in question (Davies & Logan, 2018).

Sonogram: a picture generated from sound waves.

Sonography: process of generating an image from ultrasound; used interchangeably with the term “ultrasonography.”

Specificity: ability of a diagnostic test to detect who does not have the disease in question (Davies & Logan, 2018).

Ultrasonography: process of generating an image from ultrasound (Moore & Copel, 2011).

Ultrasound: a sound wave that is at an acoustic frequency above that which humans can hear (Moore & Copel, 2011).

ACKNOWLEDGEMENTS

The classic saying “If I have seen further, it is by standing on the shoulders of Giants” is something of a maxim that has defined my journey through the past two years of my studies. Here’s to the Giants who have given me a shoulder to stand on:

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Lucy, your light has helped made me find meaning in all that I do.

And Megan, your love and devotion have helped me see further than I could have ever imagined.

INTRODUCTION

The future of health care goes hand in hand with technology, and NPs must embrace emerging technologies in order to stay relevant in the coming years. One such technology involves compact, portable ultrasound machines that are transported to a patient's location and operated by the health care provider who is treating the patient; the images generated can then immediately be integrated into patient care (Díaz-Gómez et al., 2021; Moore & Copel, 2011; Smallwood & Dachsel, 2018; Soni et al., 2020). Collectively, this process is known as point-of-care ultrasonography (POCUS). The use of POCUS in clinical practice has been shown to increase diagnostic accuracy, facilitate safer procedures, and bridge health care access gaps in resource-limited settings (Díaz-Gómez et al., 2021; Lyon et al., 2005; Micks et al., 2016; Moore & Copel, 2011; Smallwood & Dachsel, 2018). NPs stand to benefit from the versatility of POCUS because they provide comprehensive primary care services in a wide range of clinical settings where access to health resources is often limited, such as mobile health units, street health, and home care in urban, rural, and remote geographic locations (CNA, 2016). For example, an NP who works in a remote community where access to diagnostic imaging can only be acquired through air travel may use POCUS to rule out the presence of an ectopic pregnancy, thereby negating the need to transfer the patient for a formal ultrasound scan.

Despite the many benefits of POCUS, there is consensus among health care safety advocates, radiologists, and POCUS experts that the technology is user-dependent and therefore requires proper training to be operated safely (American Academy of Family Physicians [AAFP], 2016; American College of Emergency Physicians [ACEP], 2016; Canadian Association of Radiologists [CAR], 2013; Chawla et al., 2019; Lewis et al., 2019; Moore & Copel, 2011; Society of POCUS [SPOCUS], 2018). The inappropriate use of POCUS can result in patient harm by leading to either inappropriate action or inappropriate inaction, a paradoxical increase in the use of health care resources due to more testing stemming from findings based on POCUS, or unnecessary worry due to false positive or negative diagnoses (CAR, 2013; Chawla et al., 2019; Moore, 2018; Smalley et al., 2020). Certain medical specialties have addressed these concerns by establishing recommended POCUS educational curricula and competencies that are unique to their respective specialty (AAFP, 2016; ACEP, 2016; Levitov et al., 2016; Lewis et al., 2019; Smallwood & Dachsel, 2018). It is almost certain that NPs are currently operating POCUS in their clinical practice; however, little is known about the education that NPs require to competently operate POCUS devices and interpret the resulting images. To address this gap in the literature, an integrative review was conducted to establish current POCUS education programs and understand how these programs apply to NPs. The results of this integrative review are intended to provide a body of literature to influence research, practice, and policy initiatives related to NP POCUS (Whittemore & Knafl, 2005). Using the province of British Columbia (BC) as context, this discussion reviews the current landscape of primary health care in BC, provides a profile of NPs in primary care settings, summarizes the history and current clinical applications, education, and credentialing of POCUS, and details the results of a literature search culminating in recommendations stemming from an integrative review investigating the following question: What education do NPs need to competently operate POCUS in BC primary care settings?

CHAPTER ONE: BACKGROUND

This chapter will provide context for each individual component of the research question. In addition, an overview of the primary health care system in BC will be provided, as will the profiles of primary care providers, with an emphasis on NPs, regulation, and scope of practice in BC. The history, technology, profile, clinical application, and current education, credentialing, and competencies of POCUS will also be reviewed.

Primary Health Care in British Columbia

Flanked by the Pacific Ocean to the west, the Rocky Mountains to the east, the Yukon to the north, and the United States of America (USA) to the south, BC is the westernmost province in Canada and home to an estimated population of 5.2 million people (Statistics Canada, 2021). and are spread out across 944,735 square kilometres of rivers, forests, and mountains (Destination BC, n.d.). The land mass of BC is larger than that of France and Germany combined, but it contains only a fraction of the population, the vast majority of which lives in the southern part of the province (Destination BC, n.d.). Many parts of BC are rural and remote, often marked by rugged terrain with limited access points, particularly in the winter months, when conditions can limit travel to and from these communities. BC's ecogeographical diversity is a treasure, but it places an incredible strain on the finite resources of its public health care system.

Since 2018, primary health care in BC has been undergoing a major transformation to improve access to primary care services, reduce wait times for diagnostic tests, increase patient attachment with primary care providers, and alleviate pressure on hospitals (Government of BC [GOVBC], 2020; Ministry of Health, 2014; Ministry of Health, 2021). The heart of the primary health care transformation is the creation of primary care networks, which are clinical networks of local primary care providers such as NPs, family physicians (FPs), nurses, social workers, and pharmacists who work in a collaborative environment to provide comprehensive primary care services (General Practice Services Committee [GPSC], n.d.; GOVBC, 2020). Within these primary care networks are patient medical homes, which can take the shape of primary care clinics, community health centres, and urgent primary care centres, among other facilities (GPSC, n.d.). NPs are arguably the crown jewel of the primary care networks and perhaps the most celebrated addition to the health care system according to patients and their families (CNA, 2016; Ore & Sanders, 2021) because of their unique ability to combine traditional nursing care with advanced skills in diagnosis, medication prescribing, and consultation and referral to other health services, all while being cost-effective (CNA, 2016; GOVBC, 2018; 2020). As of December 2021, 103 NPs have joined the BC primary care networks, and another 52 NPs have been serving in other BC primary care settings since 2018 (GOVBC, 2021). One example of the impact of NPs on BC's primary health care transformation is the opening of four new NP-led primary care clinics. These clinics have attached 2,975 patients in just over two years (GOVBC, 2021) and they have received so much interest that one clinic's website crashed on its opening day due to overwhelming public demand (Kines, 2020).

Primary Care Settings

There is no universal definition of a primary care setting because of the wide spectrum of primary care services that can be offered; however, primary care settings can take the shape of primary care clinics, walk-in medical clinics, community health centres, residential care homes, outpatient clinics, street health centres, prisons, and many other facilities. Primary care settings, especially in rural and remote geographic areas, but also in most urban areas, often lack on-site diagnostic imaging; therefore, these tests are usually requested by an NP, then performed at offsite locations, where results can take hours to several days to receive. Virtual health, such as telehealth, offers primary care services through the use of remote technology without a health care provider being physically present. For clarity, virtual health is excluded where primary care settings are discussed in the context of this document.

Primary Care Providers

The phrase "primary care providers" will be used to refer to NPs and FPs who provide primary care services to patients, their families, and their communities. To contextualize and provide clarity to this discussion, it is necessary to briefly compare and contrast the FP and NP roles, given that the two groups share many practice similarities but differ substantially in terms of educational epistemology, regulation, and scope of practice in BC.

Family Physicians

FPs are professionals who have completed medical school and an additional two years of postgraduate training in family medicine; they then provide medical care in the form of health promotion and illness prevention, coordinate care with other health professionals, and manage a wide range of undifferentiated acute and/or chronic diseases across the patient's lifespan. This work is usually performed by FPs in primary care clinics (Canadian Medical Association [CMA], 2019). Once their training is complete, FPs are eligible to be certified by the College of Family Physicians of Canada (CFPC) to practice family medicine, but they must first be registered with the College of Physicians and Surgeons of British Columbia (CPSBC) before they can legally practice medicine in BC (CMA, 2019; CPSBC, n.d.). The scope of practice of FPs in BC is defined by section three of the *Medical Practitioners Regulation* (2020); it should be noted that restricted activities in which FPs can participate are to be identified in section 4 of this Regulation, but no restricted activities have actually been listed yet.

FPs may opt to complete an additional third year of postgraduate training in emergency medicine (CMA, 2019). While there is a recognized and dedicated emergency medicine specialist program offered by the Royal College of Physicians and Surgeons of Canada, the CFPC indicates that emergency medicine has its roots in family medicine (Collaborative Working Group on the Future of Emergency Medicine in Canada, 2016). There are at least 2,924 FPs in BC without official emergency medicine certification who still provide some degree of emergency care to patients (Collaborative Working Group on the Future of Emergency Medicine in Canada, 2016); this corroborates the CFPC's position that family medicine and emergency medicine are intrinsically linked.

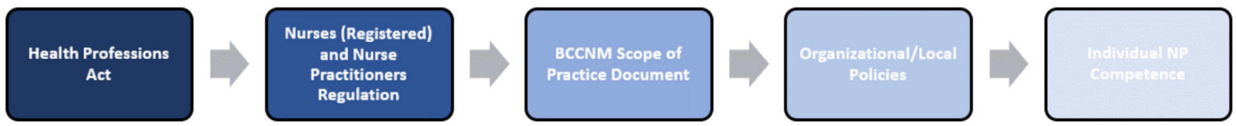
Nurse Practitioners

The CNA (2010) defines NPs as "autonomous health professionals with advanced education [who] provide essential health services grounded in professional, ethical, and legal standards" (p. 5). While there is significant clinical practice overlap between FPs and NPs, the primary difference lies in their educational preparation. NPs have completed graduate-level education, have prior clinical experience as registered nurses, and hold advanced nursing practice competencies in direct comprehensive care, health system optimization, research, and leadership, among other fields (CNA, 2019). NPs build on their foundational nursing knowledge with advanced nursing education to acquire the knowledge, skills, and abilities to diagnose diseases, prescribe medications, order diagnostic tests, perform minor surgical procedures, and consult and refer to other health professionals (CNA, 2010; 2019). The daily clinical activities of NPs include providing health care services for acute episodic illnesses and chronic conditions, such as diabetes or hypertension, to patients across their lifespan (Johnson & MacDonald, 2021) in a wide range of settings, including government-funded community clinics, private clinics, family health networks, emergency rooms, street health facilities, hospitals, and outpatient clinics (CNA, 2016). NPs diagnose and manage a wide range of diseases autonomously, but a cornerstone of NP practice worth highlighting is its collaborative nature (CNA, 2010; 2019; Johnson & MacDonald, 2021). NPs excel at team-based patient care and may collaborate with any number of health care professionals to provide culturally appropriate and safe patient care. For example, NPs may collaborate with registered psychotherapists for cognitive behavioural therapy, registered dietitians for nutritional and weight management expertise, or medical specialists such as orthopaedic surgeons for joint replacements. While NPs are versatile health care providers capable of offering comprehensive care services, they also have a well-defined scope of practice to ensure that they provide safe, ethical, and compassionate care.

Regulation and Scope of Practice. In BC, the scope of practice for NPs is set by the *Nurses (Registered) and Nurse Practitioners Regulation* (2008), which is a section of the *Health Professions Act* (1996). The BC College of Nurses and Midwives (BCCNM) is the regulatory college that manages the licensure of BC NPs and sets the standards, limits, and conditions for NP scope of practice pursuant to the *Nurses (Registered) and Nurse Practitioners Regulation* (BCCNM, 2021). NPs who are employed by one of BC's six health authorities or within Providence Health Care must apply for health authority privileges through the BCMQI NP Clinical Privileges Dictionary, henceforth referred to as the Dictionary, which determines their local scope of practice within a given health authority (BCMQI, n.d.; BCMQI, 2019). The Dictionary does not apply to NPs who are not employed by a health authority (BCMQI, n.d.); instead, these NPs must follow the policies and procedures of the organization within which they practice. Lastly, individual NPs are expected to determine their own competence to safely carry out an assessment or procedure. See Figure 1 for a visual representation of the various controls on NP scope of practice in BC.

Figure 1

Controls on Nurse Practitioner Scope of Practice in British Columbia



Note. Adapted from the BCCNM (2021).

As of May 2018, there are 426 practicing NPs in BC (GOVBC, 2018). These NPs hold practice licenses in one of the three BCCNM licensing streams: the family stream, which encompasses everyone from infants to older adults; the adult stream, which includes only adults and the older adult population; and the pediatric stream, which is limited to infants and adolescents (BCCNM, n.d.). BC NPs may belong to any one of the three streams; however, 90% of BC NPs belong to the family stream (College of Registered Nurses of British Columbia, 2017; as cited in British Columbia Nurse Practitioner Association [BCNPA], 2017), and 64% of these NPs practice in some form of primary care setting (BCNPA, 2017). Furthermore, all three NP training programs in BC are family practice-based programs; this discussion will therefore focus on those NPs who are registered in the family stream and practice in primary care settings.

Point-of-Care Ultrasonography

In 1987, ultrasonography was touted as the stethoscope of the future, but reports of ultrasonography in medical science first emerged in 1949, when the technology was adapted from World War I-era sonar technology (Soni et al., 2020). At that time, it was used medically to find bowel disease (Soni et al., 2020; Watts, 2009). The seminal article on ultrasonography in medical practice, however, was published in The Lancet by Donald et al. (1958), who reported on the capability of ultrasonography to detect a gravid uterus, pelvic tumours, and ascites.

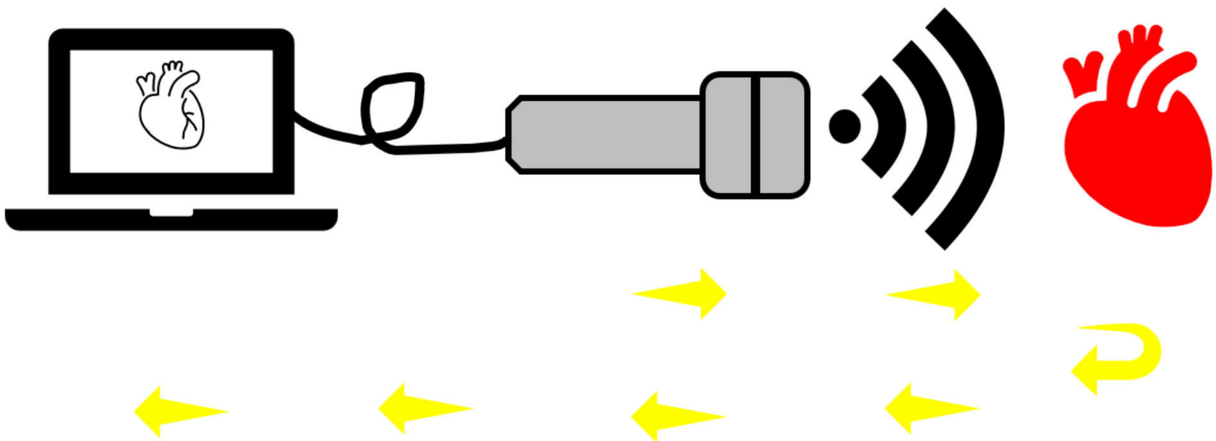
Ultrasound technology evolved over the course of the 1970s and 1980s, but it was not until the 1990s that ultrasonography became universally recognized within the medical community as a tool that could expedite diagnosis and guide treatment at the patient's location (Soni et al., 2020). Ultrasound technology continued to advance and become more compact throughout the 1990s and 2000s. In the 2010s, the compact machines became so affordable that interest in and research on ultrasonography, as well as its integration into clinical practice, began to explode (Moore & Copel, 2011). The compact, portable ultrasonography devices initially had many names, such as bedside ultrasound, focused ultrasound, or clinical ultrasound (SPOCUS, 2018), but the most universally agreed-upon name is point-of-care ultrasonography, which reflects both its portability and its clinical operation by the treating health care provider at the patient's location (Díaz-Gómez et al., 2021; Moore & Copel, 2011; Soni et al., 2020).

How the Technology Works

Despite the advances in ultrasound technology, the principles that underpin the physics of ultrasonography remain largely unchanged since its inception. Ultrasonography involves using a probe connected to a computer to send sound waves, known as ultrasound waves, through body tissues. These ultrasound waves reverberate off various structures within the body, causing different sound densities to travel back to the probe, which then transmits these sound waves to the connected computer to generate an image (Mayette & Mohabir, 2020). For example, to assess the heart, the ultrasound probe is placed on a patient's chest and sends sound waves through the patient's external chest to the heart and adjacent structures, generating various ultrasound waves which are detected by the ultrasound probe. The probe then transmits these waves to an attached computer to generate an image of the heart. See Figure 2 for a visual representation of ultrasound image generation.

Figure 2

Schematic Diagram of Ultrasound Image Generation



Note. The probe sends ultrasonic waves to the heart, then receives the reverberated sound waves and transmits them to a computer to construct an image.

While the detailed physics of ultrasonography are beyond the scope of this discussion, it is important to review the different modes of ultrasonography, as they are pertinent to how POCUS can be used in primary care settings. There are three modes that have the greatest benefit for primary care providers. First, the two-dimensional mode, which is commonly referred to as B-mode, is the default mode of most ultrasound machines; it is used to generate an image based on the echogenicity (brightness) of the object of interest and its adjacent structures (Mayette & Mohabir, 2020). The second mode is motion mode, henceforth referred to as M-mode, which is used to detect motion and is the ideal mode for dynamic structures such as cardiac motion or lung movement (Mayette & Mohabir, 2020). The third mode is Doppler mode, which is used to visualize and calculate blood flow through blood vessels and fluid-filled structures (Mayette & Mohabir, 2020). In Doppler mode, the ultrasound computer can produce a sound audible to the human ear and generate an image that can be interpreted. The Doppler mode is most commonly known to nurses, who often use it to detect fetal heart sounds in utero and to assess upper or lower extremity pulses in the context of vascular disease (Benbow, 2014).

Differences Between Ultrasonography Modalities

Consultative ultrasonography and POCUS share many technical similarities, but they differ substantially in terms of their respective integration into patient care. Consultative ultrasonography has several different names in the literature, such as comprehensive ultrasound examination (Chawla et al., 2019), consultative diagnostic ultrasound (CAR, 2013), and consultative ultrasonography (Díaz-Gómez et al., 2021); however, they all refer to the same process. For clarity, this discussion will use consultative ultrasonography as an all-inclusive term. Consultative ultrasonography is the process by which an ultrasound scan is ordered by the treating health care provider to assist with diagnosis and/or guide treatment (SPOCUS, 2018). The patient must then wait for an appointment for the scan, which can take hours or days depending on the availability of ultrasound equipment and a technician to perform the test. Once an appointment time has been arranged, the patient must travel to a designated radiology clinic or hospital, where the ultrasound examination will be performed by the technician with a large, bulky ultrasound machine capable of producing comprehensive images (Díaz-Gómez et al., 2021; Soni et al., 2020). The resulting images are then interpreted by a radiologist, who is not directly involved in the patient's care or at the same location as the patient. The radiologist then provides a consultation note on their findings to the treating health care provider (Díaz-Gómez et al., 2021). When considering the overall workflow, the time it takes to perform the scan, and the time required for the radiologist to interpret the image, the overall process of consultative ultrasonography can often take several hours (Soni et al., 2020) or even days, depending on resource availability. It is also important to note that images produced using consultative ultrasonography are intended to be comprehensive, often evaluating many structures beyond what the scan was requested to assess in the first place. For example, an NP who orders a consultative ultrasonography scan to assess for appendicitis will receive images from a technologist and comments from a radiologist on the patient's appendix, spleen, liver, kidneys, and adjacent abdominal organs.

On the other hand, POCUS uses a compact, sometimes pocket-sized ultrasound machine that is transported to the patient's location. POCUS is performed by the treating health care provider, often an NP or physician, and the resulting images are interpreted at the patient's location without a radiologist (Díaz-Gómez et al., 2021; Moore & Copel, 2011; Soni et al., 2020). The images are immediately integrated to detect acute, potentially life-threatening conditions in order to expedite patient care (Soni et al., 2020). Moreover, POCUS can also easily be repeated, providing dynamic assessments and re-assessments in real time as the patient's condition warrants, whereas consultative ultrasonography only provides a single assessment captured at one moment in time (Moore & Copel, 2011; Soni et al., 2020). It is important to note that POCUS is not intended to be comparable to or replace the information acquired through consultative ultrasonography; instead, POCUS enhances the physical examination by providing more data points, which can then be used to answer specific clinical questions related to specific clinical situations (American Academy of Family Physicians, 2016; Chawla et al., 2019; Díaz-Gómez et al., 2021; Levitov et al., 2016; Lewis et al., 2019; Smallwood & Dachsel, 2018; SPOCUS, 2018; Soni et al., 2019; Patel et al., 2021). For example, POCUS can help a clinician rule out an ectopic pregnancy by enhancing a clinician's physical examination findings by showing an image of an intrauterine pregnancy (Stein et al., 2010). Unlike POCUS, consultative ultrasonography systematically maps normal and abnormal anatomy function and provides guidance on interventional procedures by a trained imaging specialist (Chawla et al., 2019).

While providing the final interpretation of consultative ultrasonography images is the responsibility of radiologists, POCUS is inclusive, meaning that it is not limited to any one health profession or specialty, protocol, or organ system (Díaz-Gómez et al., 2021; Moore & Copel, 2011). In fact, there are reports in the literature describing various POCUS uses by interprofessional providers. One study found that registered nurses in an intensive care unit can accurately use POCUS to assess for pulmonary edema and estimate blood volume (Tulleken et al., 2019), another study found that respiratory therapists can learn how to use POCUS for the lungs at the same rates as physicians (See et al., 2016), and a commentary article described how POCUS has been used by physiotherapists to assist in the rehabilitation of pelvic floor muscles (Whittaker et al., 2007).

Clinical Uses of POCUS

The subject of the clinical uses of POCUS has been rigorously studied. Many of these studies have found that POCUS can increase diagnostic accuracy, facilitate safer clinical procedures, and bridge health care access gaps. Primary care, which is the practice of providing preventative, restorative, or palliative health care services for a large number of emergent, acute, and chronic health conditions to patients of all ages (Muldoon et al., 2006), arguably stands to benefit the most by integrating POCUS into its practice. This is primarily due to its versatility in managing and diagnosing a wide range of conditions. Furthermore, clinical practice patterns in primary care overlap with those in virtually all health care specialties, many of which depend on ultrasonography for diagnosis and management. In particular, emergency medicine has been viewed as a leader in developing POCUS education and competencies and determining its clinical applications (Lewis et al., 2018). As such, the vast majority of the literature related to POCUS comes from the field of emergency medicine, which would, in theory, make generalization to primary care problematic; however, primary care and emergency medicine share many similar practice patterns in Canada, and the vast majority of emergency medicine providers are FPs with or without emergency specialty training (Collaborative Working Group on the Future of Emergency Medicine in Canada, 2016). For these reasons, emergency medicine has been included in a non-exhaustive list of POCUS applications in primary care. See Table 1 for an overview of these applications.

Table 1

Select POCUS Applications in Primary Care

Organ system	Use	
	Diagnosis	**Procedure**
Dermatologic	Cellulitis[a,b,c] Abscess[a,b,c] Foreign body[a,b,c]	Incision and drainage guidance[a,c]
Ophthalmologic	Retinal detachment[a,b,c] Vitreous detachment[a,b,c] Vitreous hemorrhage[a,b,c]	
Neurologic	Increased intracranial pressure	Lumbar puncture guidance[a]
Pulmonic	Pulmonary edema[a,b] Pneumonia[a,b] Pneumothorax[a,b,c] Pleural effusion[a,b,c]	Thoracentesis guidance[a,b,c]
Cardiovascular	Heart failure[a,b,c] Fluid volume status[a,b,c] Pericardial effusion[a,b] Cardiac tamponade[a,b,c] Abdominal aortic aneurysm[a,b,c] Deep vein thrombosis[a,b,c]	
Abdominal	Free fluid in the abdominal cavity[a,b,c] Ascites[a,b,c] Appendicitis[a,c] Small bowel obstruction[a,c] Cholelithiasis[a,b,c] Nephrolithiasis[a,c] Hydronephrosis[a,c]	Paracentesis guidance[a,b,c]
Obstetric	Intrauterine pregnancy[a,b,c] Fetal dating and measurements[a] Ectopic pregnancy[a,b,c]	

Organ system	Use	
	Diagnosis	Procedure
Musculoskeletal	Bone fracture[a,b,c] Joint effusion[a,b,c]	Joint aspiration and injection guidance[a,b,c]
Pediatric	Appendicitis[a,c] Intussusception[b,c] Skull fracture[b] Radial fractures[b,c]	

Note. The suggested uses POCUS applications in primary care are a composite of guidelines and uses suggested in the literature.

[a] Reflects possible applications as suggested by the AAFP (2016).

[b] Reflects possible applications as suggested by Lewis et al. (2019).

[c] Reflects possible applications as suggested by the ACEP (2016).

Dermatologic

Skin and soft tissue infections are one of the most common conditions encountered in ambulatory and outpatient care settings. While Canadian statistics are not available, American statistics from 1997-2005 show that 14.2 million primary care visits were related to skin and soft tissue infections, more than 95% of which were related to cellulitis and skin abscesses (Hersh et al., 2008). Differentiating between cellulitis, which is an inflammation of the layers of the skin, and an abscess, a closed collection of bacteria under the surface of the skin, is often difficult. These two conditions also often occur simultaneously and can lead to septicemia if not treated properly (Barbic et al., 2017). Furthermore, the treatment regimes for cellulitis and abscess differ substantially, with the former requiring antibiotic medication and the latter requiring incision and drainage (Barbic et al., 2017). Traditionally, primary care providers would need to prescribe antibiotics for cellulitis and request consultative ultrasonography to rule out a concomitant abscess; however, POCUS has been identified as a tool that can help the primary care provider identify the presence of an abscess immediately.

A systematic review and meta-analysis of eight studies found that the use of POCUS compared to physical examination for the diagnosis of abscess in emergency department patients with skin and soft tissue infections had a pooled sensitivity of 96.2%, 95% CI [91.1%, 98.4%], a specificity of 82.9%, 95% CI [60.4%, 93.9%], a positive likelihood ratio of 5.63, 95% CI [2.2, 14.6], and a negative likelihood ratio of 0.05, 95% CI [0.01, 0.11] (Barbic et al., 2017). These findings were consistent with another systematic review and meta-analysis of six studies with similar inclusion and exclusion criteria (Subramaniam et al., 2016). If an abscess is identified, the standard treatment is incision and drainage, but if this is performed incorrectly, it can cause abscess recurrence and necessitate repeat incision and drainage. Gaspari et al. (2019) found that physical examination combined with POCUS had fewer instances of failed incision and drainage of an abscess compared to physical examination alone.

The use of POCUS as an adjunct to history and physical examination to detect foreign bodies in the skin is also promising. A systematic review of 17 articles found that the use of POCUS has a pooled specificity of 92%, 95% CI [88%, 95%] for the detection of foreign bodies in soft tissue (Davis et al., 2015).

Ophthalmologic

Ocular conditions accounted for 3.4% of all emergency department visits from 2001-2014 in one health network in the USA (Stagg et al., 2017). While Canadian statistics are not available, it is reasonable to assume that Canadians would similarly seek medical care for ocular conditions regularly. One of the most emergent ocular conditions necessitating immediate care is retinal detachment, because it can result in permanent blindness if left unrecognized or untreated. However, retinal detachment has many symptoms which overlap with the less serious conditions of vitreous detachment or hemorrhage (D'Amico, 2008). Using POCUS in addition to obtaining a history and conducting a physical examination has been shown to accurately identify and differentiate between vitreous hemorrhage and retinal and vitreous detachment (Lahham et al., 2019). Gottlieb et al. (2019a) conducted a systematic review and meta-analysis of 11 articles and found that POCUS has a 94.2% sensitivity, 95% CI [78.4%, 98.6%], a 96.3% specificity, 95% CI [89.2%, 98.8%], a positive likelihood ratio of 25.2, 95% CI [8.1, 78.0], and a negative likelihood ratio of 0.06, 95% CI [0.01, 0.25] for the diagnosis of retinal detachment. The subgroup analysis is also noteworthy because it was found that the use of POCUS by non-emergency department health care providers had a sensitivity of 91.1%, 95% CI [67.5%, 98.0%] and a specificity of 98.6%, 95% CI [81.7%, 99.9%] for the diagnosis of retinal detachment.

Neurologic

Clinical presentation of increased intracranial pressure (ICP) in primary care settings is rare, but a failure to identify or properly diagnose increased ICP can result in substantial morbidity and mortality. The etiology of increased ICP is often associated with blunt force trauma to the skull or massive intracranial hemorrhage, but other causes of increased ICP can be more subtle and include concussions or metabolic causes such as hyponatremia. The latter is often found in elderly patients who take selective serotonin reuptake inhibitor medications. The current standard for directly measuring ICP is through the use of an intracerebral catheter, which is highly invasive, resource-intensive, and not suitable for primary care settings (Raffiz & Abdullah, 2017). Many clinicians therefore turn to computed tomography (CT) scans to indirectly assess for increased ICP. POCUS has been identified as an adjunct to physical examination to identify increased ICP by quantifying the diameter of the optic nerve sheath. In a systematic review and meta-analysis of 478 participants in 12 studies, Ohle et al. (2015) found that optic nerve sheath diameter assessment with POCUS was comparable to CT scans of the head when assessing for increased ICP. This is particularly helpful in primary care settings, where access to CT scanners or intracerebral catheters is not available and the need to diagnose increased ICP is a priority.

Lumbar punctures are a common procedure among primary care providers because the cerebrospinal fluid acquired from the procedure can provide valuable clues to inform a diagnosis of viral and bacterial meningitis, neurosyphilis, cerebral abscess, multiple sclerosis, and subarachnoid hemorrhage (Seehusen et al., 2003). Unfortunately, lumbar punctures are a notoriously difficult procedure; one study of lumbar punctures in pediatric patients showed a success rate of only 50-60% (Glatstein et al., 2011), and there was a 35% chance of traumatic or unsuccessful lumbar puncture in adults (Perry et al., 2015). Furthermore, cerebrospinal fluid contaminated with blood or where the sterile field had been broken can lead to false results or worse, nosocomial infection. Gottlieb et al. (2019b) found that, when compared to traditional physical landmark-based lumbar puncture, POCUS-assisted lumbar puncture was successful 8.9%, 95% CI [1.2%, 16.7%] more often and had a -16.4%, 95% CI [-27.6%, -5.2%] reduction in traumatic lumbar puncture, a -1.8 minute, 95% CI [-3.57, -0.03] decrease in procedural time, 0.61, 95% CI [-1.00, -0.23] fewer attempts, and a -2.53, 95% CI [-3.89, -1.17] reduction in pain on a 10-point Likert scale. That said, Kirschner et al. (2019) argued in a commentary paper that the increased success rate of lumbar puncture in adults found in the above Gottlieb et al. (2019b) study is controversial and may apply more accurately to pediatric patients than adults.

Pulmonic

Cough and respiratory symptoms are among the top ten reasons why people seek health care services worldwide (Finley et al., 2018), and they are the second-most frequent problems for which Canadians seek emergency care (Canadian Institute for Health Information [CIHI], 2019).

The chest radiograph has long been considered the diagnostic test of choice for assessing pulmonary pathology, but POCUS has increasingly challenged this notion. Perhaps the most widely studied use of POCUS for pulmonary pathology involves the detection of pulmonary edema as the cause of acute dyspnea. Maw et al. (2019) published a landmark systematic review and meta-analysis of six studies comparing POCUS to chest radiography for diagnosing cardiogenic pulmonary edema in patients experiencing dyspnea in any clinical setting. While the studies in question primarily included patients with acute dyspnea in hospital wards and emergency departments, Maw et al. (2019) found that POCUS had a pooled estimated sensitivity of 0.88, 95% CI [0.75, 0.95] and a specificity of 0.90, 95% CI [0.88, 0.92], compared to chest radiography, which had a sensitivity of 0.73, 95% CI [0.70, 0.76] and a specificity of 0.90, 95% CI [0.75, 0.97] for detecting the presence of cardiogenic pulmonary edema. These findings suggest that POCUS is actually superior to the chest radiograph for ruling out cardiogenic pulmonary edema and that it is particularly useful in primary care, as it can support the optimization of pharmacotherapeutics or referral to the most appropriate specialty services.

In another systematic review and meta-analysis of seven articles that included 1075 patients in two emergency departments, two intensive care units, two inpatient hospital wards, and one prehospital setting, Al Deeb et al. (2014) found that the sensitivity of POCUS for the diagnosis of acute pulmonary edema was 94.1%, 95% CI [81.3%, 98.3%], with a specificity of 92.4%, 95% CI [84.2%, 96.4%]. The integration of these findings into clinical practice is particularly helpful in ruling out acute pulmonary edema as a cause of acute dyspnea in clinical situations where the pretest probability of acute pulmonary edema is low.

POCUS has also been shown to be at least equivalent, if not superior, to chest radiography for the detection of consolidated pneumonia. In a systematic review and meta-analysis of 20 studies that included both adult and pediatric patients with pneumonia, Alzharani et al. (2017) found that POCUS had a pooled sensitivity of 0.85, 95% CI [0.84, 0.87] and a pooled specificity of 0.93, 95% CI [0.92, 0.95], with a positive likelihood ratio of 11.05, 95% CI [3.76, 32.5] and a negative likelihood ratio of 0.08, 95% CI [0.04, 0.15]. A prospective, observational cohort study of 200 patients under 21 years of age compared POCUS to chest radiography for the detection of suspected community-acquired pneumonia (CAP) and found that the sensitivity for CAP was equal for POCUS and chest radiography; however, POCUS had superior specificity for CAP (Shah et al., 2013).

While the evidence is evolving, it is also interesting to note that POCUS has been shown to be a highly effective and safe tool for determining the presence of Coronavirus disease 2019 (COVID-19)-associated pneumonia, the dreaded consequence of a COVID-19 infection. Gibbons et al. (2021) found that, among 110 patients with laboratory-confirmed COVID-19 who presented to an emergency department, POCUS had a sensitivity of 97.6%, 95% CI [91.6%, 99.7%] and a specificity of 33.3%, 95% CI [16.5%, 54%], compared to a sensitivity of 69.9%, 95% CI [58.8%, 79.5%] and a specificity of 44.4%, 95% CI [25.5%, 64.7%] for chest radiography for the detection of COVID-19-associated pneumonia. These findings have major implications for the prognosis and management of COVID-19-associated pneumonia in primary care, as POCUS can help rule out COVID-19-associated pneumonia, support decisions related to escalating to a higher level of care, determine isolation needs, and identify appropriate pharmacotherapeutic choices.

Pneumothorax, which is the abnormal collection of air between the pleural cavity and the lung parenchyma, can either be caused by trauma or occur spontaneously due to an underlying condition. The exact prevalence of spontaneous pneumothorax in Canada is unknown; however, spontaneous pneumothorax is estimated to have a prevalence of 24 per 100,000 men and 9.8 per 100,000 women in the United Kingdom, and patients have been known to present to family practice clinics as well as emergency departments with this condition (Bobbio et al., 2015). While spontaneous pneumothorax is rare overall, unrecognized treatment can lead to significant morbidity and death. The same can be said for traumatic pneumothorax, as the mechanism of injury is often more complex. POCUS has proven to be valuable for ruling out pneumothorax due to traumatic or spontaneous etiology. Alrajhi et al. (2012) found that POCUS is superior to chest radiography for the identification of pneumothorax, with a pooled sensitivity of 90.9%, 95% CI [86.5%, 93.9%] for the former and 50.2%, 95% CI [43.5%, 57.0%] for the latter.

POCUS has also been shown to be an effective tool to detect the presence of pleural effusion, a collection of fluid between the lungs and the pleural cavity that can arise from various diseases such as cancer, malnutrition, and infection (Light, 2002). Yousefifard et al. (2016) found that the pooled sensitivity and specificity of POCUS were 0.94 and 0.98, 95% CI [0.88-0.97 and 0.92-1], respectively, for the detection of pleural effusion, which is superior to the pooled sensitivity and specificity of chest radiography: 0.5 and 0.91, 95% CI [0.33-0.68 and 0.68-0.98], respectively. In the event that a pleural effusion is detected and a thoracentesis, which is the removal of fluid from the pleural space with a needle, is needed for diagnostic or therapeutic reasons, POCUS has been shown to decrease rates of accidental organ puncture by 10% and increase needle placement accuracy by 26% (Diacon et al., 2003). These findings suggest that POCUS can be a useful tool to screen for the presence of pleural effusion and can dramatically increase the safety of thoracentesis. This is particularly valuable in the context of primary care, where clinical practice has a heavy focus on disease screening and timely diagnosis.

Cardiovascular

It is estimated that 2.4 million Canadian adults 20 years of age or older live with ischemic heart disease, and approximately 92,900 Canadians were diagnosed with heart failure in 2017 (Public Health Agency of Canada, 2017). Heart disease is an umbrella term for the wide spectrum of heart failure, but the state of most concern is heart failure with reduced ejection fraction (HFrEF). HFrEF is defined as "a complex clinical syndrome in which there is dyspnea or exertional limitation due to impairment of ventricular filling or ejection of blood, or a combination of both" (Murphy et al., 2020, p. 1). It is more commonly found in the elderly, although young people can be affected as well (Public Health Canada, 2017). To manage HFrEF, the transthoracic echocardiogram, a type of ultrasonography ultrasound for the heart, is the mainstay for both diagnosis and determination of disease treatment and surveillance; the transthoracic echocardiogram works by evaluating myocardial contractility and the intolerance of the myocardium to increases or decreases in blood volume. While POCUS echocardiography is not meant to replace consultative echocardiography, it has been found to be a suitable method for assessing gross left ventricular function as well as valvular pathology in varying levels of blood volume (Marbach et al., 2020). A study of 104 registered nurses with appropriate POCUS training for the assessment of fluid volume status found excellent inter-rater reliability with emergency physicians with respect to appropriately assessing for hypovolemia and recommending intravenous fluids according to best practice guidelines to septic patients with or without concurrent secondary heart failure (Selden et al., 2017). The interest in POCUS echocardiography has led to the creation of the Cardiopulmonary Limited Ultrasound Examination protocol, a structured POCUS examination evaluating left ventricular dysfunction, left atrial enlargement, inferior vena cava plethora, and ultrasound lung comet-tail artifacts, which gives the treating health care provider an overall picture of heart function (Kimura et al., 2011). This could, in turn, help primary care providers recommend optimal pharmacological and non-pharmacological interventions and assist with predicting the need for hospitalization.

Pericardial effusion with subsequent cardiac tamponade is a life-threatening condition where the pericardial sac, the layer that surrounds the heart, fills with blood, pus, clots, gas, or fluid, and obstructs the heart from functioning (Spodick, 2003). The signs and symptoms of pericardial effusion can be subtle or, in some cases, silent; patients may therefore present to primary care settings with non-specific symptoms. To further complicate matters, pericardial effusion can accompany a wide spectrum of conditions, including but not limited to several types of cancer, heart failure, infection (Spodick, 2003), and even COVID-19 messenger ribonucleic acid vaccination (Hryniewicki et al., 2021; Luk et al., 2021). An echocardiogram is the diagnostic test of choice to diagnose pericardial effusion and cardiac tamponade (Spodick, 2003). An echocardiogram performed with POCUS was found to have a sensitivity, specificity, and overall accuracy of 96%, 98%, and 97.5%, 95% CI [90.4%, 98.9%], [95.8%, 99.1%], [95.7%, 98.7%], respectively, for the detection of pericardial effusion (Mandavia et al., 2001).

Abdominal aortic aneurysm (AAA) is a segmental, full-thickness dilation of the abdominal aorta which exceeds the normal vessel diameter by 50%. People with AAA are usually asymptomatic until the aorta ruptures (Kent, 2014). Approximately 20,000 Canadians are diagnosed with AAA each year, and approximately 2,000 people die of a ruptured aneurysm annually (Fitzpatrick-Lewis et al., 2015). Both the Canadian Task Force on Preventative Health Care and the United States Preventive Services Task Force recommend one-time screening for the presence of AAA in men aged 65-80 years in Canada and men aged 65-75 years in the USA who have a history of smoking tobacco (Fitzpatrick-Lewis et al., 2015; Guirguis-Blake et al., 2019). If an AAA is identified, the size of the aneurysm should be monitored to ensure that there is no rapid progression to aneurysmal rupture. POCUS has been shown to be an excellent tool for detecting AAA in symptomatic patients, with a pooled sensitivity of 99%, 95% CI [96%, 100%] and a pooled specificity of 98%, 95% CI [97%, 99%] (Rubano et al., 2013). While the aforementioned study does not include patients who have asymptomatic AAA (which is the population requiring screening), POCUS could be used in place of consultative ultrasonography to monitor AAA size progression, which would be consistent with the monitoring guidelines for established AAA according to the Canadian Society for Vascular Surgery Guidelines (Kapila et al., 2021); monitoring AAA size progression with POCUS has the potential to reduce access to, and demand for consultative ultrasonography.

Affecting approximately 45,000 Canadians each year, which translates to 2-4 patients annually in a typical Canadian family practice setting, deep vein thrombosis (DVT) is a cardiovascular condition that can lead to fatal pulmonary embolism, chronic lower leg edema, and skin atrophy if left untreated (Thrombosis Canada, 2013). Consultative ultrasonography with doppler is the gold-standard test for the diagnosis of DVT (Needleman et al., 2018; Thrombosis Canada, 2013); however, a single-centre, non-inferiority study of POCUS performed by emergency physicians compared to consultative ultrasonography with doppler found that, among 109 patients presenting with undifferentiated unilateral lower extremity swelling possibly indicative of DVT, POCUS had a sensitivity of 93.2%, 95% CI [83.8%, 97.3%] and a specificity of 90.0%, 95% CI [78.6%, 95.7%], with an accuracy of 91.7%, 95% CI [85%, 95.6%] (García et al., 2019). Pomero et al. (2013) conducted a systematic review and meta-analysis of 16 studies examining emergency physician-operated POCUS for the detection of DVT and found that POCUS had a weighted sensitivity of 96.1%, 95% CI [90.6%, 98.5%] and a weighted specificity of 96.8%, 95% CI [94.6%, 98.1%]. These study findings suggest that POCUS has the power to rule DVT in or out, but that POCUS might also be useful in monitoring the size of a DVT. This would be helpful for situations in primary care where anticoagulation or hospitalization are not required but ongoing monitoring of the DVT size is needed to identify potential concerns early (Needleman et al., 2018; Thrombosis Canada, 2013).

Abdominal Uses

Abdominal symptoms are among the top 10 reasons patients report seeking health care (Finley et al., 2018) in a primary care setting. In Canada, abdominal pain is the top reason Canadians seek emergency health care (CIHI, 2019) and the sixth-most common reason people in Ontario seek primary care (Stephenson et al., 2021). One cause of abdominal pain that can be seen in primary care is bleeding in the abdominal cavity following blunt trauma, which poses a diagnostic challenge due to vague signs and non-specific symptoms, and which often requires diagnostic imaging to determine the presence of intra-abdominal bleeding (Nishijima et al., 2012). A trial by Rozycki et al. (1993) found that the use of POCUS was 79% sensitive and 95.6% specific for the detection of free fluid in the abdomen, suggesting that POCUS has the ability to rule in free fluid, which can expedite appropriate surgical consultation and referral from primary care settings. Similar findings were corroborated in a systematic review and meta-analysis involving adult trauma patients (Nishijima et al., 2012) and the pediatric population (Tian et al., 2021).

One of the most common sources of free fluid in the abdomen unrelated to trauma is ascites, which is the pathologic accumulation of fluid in the peritoneal cavity most commonly stemming from liver disease, cancer, and heart failure (Runyon, 1994). If left untreated, the progressive accumulation of ascites can have devastating impacts on patient health, including but not limited to hypotension, secondary heart failure, abdominal sepsis, renal failure, and lower limb edema (Ginès et al., 2004). The treatment of choice for ascites is paracentesis, where a needle is inserted into the peritoneal space of the abdomen to drain the fluid that has accumulated (Ginès et al., 2004). Paracentesis is traditionally performed "blind," where a needle is inserted into the peritoneum based on physical landmarks of the abdomen. Common complications of "blind" paracentesis include bowel perforation, bleeding, and iatrogenic infections (Nazeer et al., 2005). In a randomized trial of 100 patients requiring paracentesis in the emergency department, the use of POCUS when performing paracentesis resulted in a 95% success rate compared to "blind" paracentesis, which had only a 61% success rate (Nazeer et al., 2005).

Another cause of free fluid in the abdomen can be appendicitis, an inflamed appendix that can rupture and cause serious health effects. Al-Omran et al. (2003) found that there were 65,675 cases of appendicitis in Ontario between 1991 and 1998, 33% of which resulted in a rupture. Because appendicitis typically occurs in the pediatric population and young adults, the test of choice to diagnose appendicitis is ultrasonography, because no ionizing radiation is used; this decreases the risk of cancer later in life (Pare et al., 2015). One systematic review and meta-analysis of 17 studies found that POCUS had a pooled sensitivity and specificity of 84%, 95% CI [72%, 92%] and 91%, 95% CI [85%, 95%], respectively, for the detection of appendicitis. Furthermore, POCUS had a positive likelihood ratio of 7, 95% CI [3.2, 15.3] and demonstrated no significant differences compared to radiologist-performed ultrasonography for the detection of appendicitis (Lee & Yun, 2018). While the findings of this study make ruling out appendicitis with POCUS controversial, the high specificity and positive likelihood ratio suggest that POCUS is capable of ruling in appendicitis, which can help the primary care provider and the patient make more informed choices for treatment plans and additional tests, if needed.

Free fluid in the abdomen can also be present with small bowel obstruction (SBO), a functional or mechanical impedance of the small bowel resulting in decreased bowel transit. Diagnosing SBO can be challenging, as the signs and symptoms can range from mild nausea to septic shock. The wide spectrum of possible clinical presentation necessitates timely diagnosis with diagnostic imaging of the abdomen using either radiography or a CT scan (Gottlieb et al., 2018). In fact, one population-based study in Ontario, Canada found that the 1-year mortality rate of SBO was 13.9%, 95% CI [13.4%, 14.3%] between 2005 and 2011 (Behman et al., 2019). If SBO is detected, emergency consultation with surgery is needed, because the mortality associated with SBO is high (Gottlieb et al., 2018). POCUS has been viewed as an alternative to radiography or CT scans for the diagnosis of SBO. Gottlieb et al. (2018) conducted a systematic review and meta-analysis of 11 studies involving 1178 patients across four continents which found that the pooled sensitivity and specificity of POCUS for the detection of SBO were 92.4%, 95% CI [89%, 94.7%] and 96.6%, 95% CI [88.4%, 99.1%], respectively, with positive and negative likelihood ratios of 27.5, 95% CI [7.7, 98.4] and 0.08, 95% CI [0.06, 0.11], respectively. Ultimately, the findings from this study suggest that POCUS has value for detecting SBO in primary care settings where access to radiography or a CT scanner is limited and a timely referral to surgery is needed.

Cholelithiasis, a condition in which gallstones are detected, can lead to infection; the patient can progress to cholecystitis, a life-threatening infection of the gallbladder that can result in septic shock and death if it continues unrecognized and untreated (Peterson, 2020). Consultative ultrasonography is the gold-standard diagnostic test to diagnose cholelithiasis; POCUS is a tool that has shown to detect cholelithiasis as well. A systematic review and meta-analysis by Ross et al. (2011) found that emergency physicians using POCUS were able to detect the presence of cholelithiasis with a sensitivity and specificity of 89.8% and 88%, 95% CI [86.4%, 92.5%], [83.7%, 91.4%], respectively. The comparable sensitivity and specificity of POCUS to consultative ultrasonography for the detection of cholelithiasis can effectively rule out cholecystitis if no gallstones are visualized. Patients in primary care settings with abdominal pain consistent with cholelithiasis stand to benefit from the use of POCUS, as other causes of abdominal pain can be considered once cholecystitis has been ruled out.

Perhaps one of the more exciting features of POCUS is its ability to detect nephrolithiasis and its associated complication of hydronephrosis, which can result in a life-threatening kidney infection and kidney failure if left untreated. While a CT scan of the kidney, ureter, and bladder (CT KUB) is considered the ideal diagnostic imaging choice for the diagnosis of nephrolithiasis and its complications, the increased risk of cancer associated with the ionizing radiation from CT scans is undesirable for young adults and pregnant people. POCUS has emerged as an alterative to CT KUB for the detection of nephrolithiasis and its complications. Smith-Bindman et al. (2014) found that the sensitivity of CT KUB, POCUS, and consultative ultrasonography for the diagnostic accuracy of nephrolithiasis were 54%, 57%, and 88%, 95% CI [48%, 60%], [51%, 64%], [84%, 92%], respectively, while the specificity was 71%, 73%, and 58%, 95% CI [67%, 75%], [69%, 77%], [55%, 62%], respectively, and there was no difference in high-risk diagnosis with complications. These findings are promising for patients in primary care settings for whom a diagnosis of nephrolithiasis is suspected but the risks of CT scans exceed the benefits. POCUS can be used without increased risks of missed high-risk diagnosis and complications.

Pelvic, Gynecologic, and Obstetric Uses

As previously mentioned, the doppler ultrasound is a common tool for assessing cardiovascular flow (Benbow, 2014), but it has also been used to assess the rate, rhythm, and presence of fetal heart tones in pregnant people (Cordero, 2003). Assessing fetal heart tones is considered the standard of care for people who are 10 weeks pregnant or more and this should be done during each encounter with a primary care provider (Bickley et al., 2021). The absence of fetal heart tones is considered abnormal and requires consultative ultrasonography to detect fetal viability (Bickley et al., 2021). Performing consultative ultrasonography and acquiring the radiologist's report of findings can take several hours or longer in primary care. Given that pregnancy-related visits were ranked as the 10th and 7th most common reason in Ontario to seek primary care before and after the COVID-19 pandemic, respectively (Stephenson et al., 2021), the need for some form of ultrasonography for obstetrical care is increasingly vital. While consultative ultrasonography has been the mainstay for fetal size measurements and the assessment of developmental milestones, the Society of Obstetrics and Gynaecologists of Canada recommends the use of POCUS for routine assessments involving the confirmation of intrauterine pregnancy, fetal viability, placental and fetal location within the uterus, estimating gestational age, facilitating the external manual repositioning of the fetus within the uterus, and conducting fetal assessments before breech vaginal and caesarian deliveries (Jain et al., 2021).

With respect to obstetrical concerns in primary care, POCUS can detect an ectopic pregnancy, a condition where a fetal embryo implants outside the uterus and causes a life-threatening hemorrhage as the embryo grows (Barnhart, 2009). While Canadian statistics regarding ectopic pregnancies are unavailable, an estimated 1-2% of all pregnancies are ectopic and account for 75% of all maternal deaths in the first trimester and 9-13% of all pregnancy-related deaths (Po et al., 2021). It is therefore paramount that primary care providers be on the lookout for early ectopic pregnancy to reduce maternal morbidity and mortality. However, the standard history and physical examination findings lack specificity for the early detection of ectopic pregnancy, and when combined with the inherent delays of consultative ultrasonography, the best test to determine the presence of ectopic pregnancy, this collectively puts the health of pregnant patients at risk. POCUS has been found to have a pooled sensitivity of 99.3%, 95% CI [96.6%, 100%], a negative predictive value of 99.96%, 95% CI [99.6%, 100%], and a negative likelihood ratio of 0.08, 95% CI [0.025, 0.25] for the detection of ectopic pregnancy (Stein et al., 2010). The findings from this study suggest that POCUS can be used to rule out ectopic pregnancy and can be useful in primary care settings to avoid delay in diagnosis.

Musculoskeletal

The 7th most common reason to seek primary care in Ontario is musculoskeletal pain (Stephenson et al., 2021). While there are many causes of musculoskeletal pain, common reasons for joint pain include osteoarthritis and calcified tendinitis. In addition to pharmacological and non-pharmacological pain management strategies, intra-articular injections of cortisone to decrease the inflammation of the condition are often performed. These injections were historically administered “blind,” akin to paracentesis, and carried similar risks of damage to the adjacent structures, blood vessels, and nerves; however, the addition of POCUS can improve needle placement and reduce iatrogenic injury (Arnold et al., 2020). Similarly, joint aspiration of the fluid that has collected within the joints can be made safer with the addition of POCUS. In fact, the Dictionary has recognized the improved safety profile of POCUS and included it in its privileging document as a non-core privilege that can be requested (BCMQI, 2019).

The addition of POCUS to detect fractures has also been reported in the literature. Chartier et al. (2017) conducted a systematic review and meta-analysis of 30 studies examining the utility of POCUS in ruling long bone fractures (radius, ulna, femur, tibia, and fibula) in and out, which found a pooled sensitivity of 89.5%, 95% CI [77%, 95.6%], a specificity of 94.2%, 95% CI [86.1%, 97.7%], a positive likelihood ratio of 16.4, 95% CI [6.57, 33.5], and a negative likelihood ratio of 0.12, 95% CI [0.05, 0.24]. The authors of the article are hesitant to suggest that POCUS should replace standard radiography for the detection of long bone fractures; however, in primary care settings where radiography is not available, POCUS may be a reasonable option to assess for fractures in patients for whom clinical suspicion of long bone fracture is low, but some form of diagnostic imaging is required to support this suspicion. It stands to reason that POCUS may also support proper bone alignment following the application of an immobilization device, such as a cast, until definitive care is accessed.

Pediatric

Children stand to benefit from the use of POCUS because of the lack of ionizing radiation, which increases the risk of cancer later in life, and due to the fact that children have higher water content and smaller statures; these factors allow for improved ultrasound amplitude and shorter distances for these amplitudes to travel (Conlon et al., 2020). One use of POCUS in the pediatric population is determining the presence of appendicitis. Benabbas et al. (2017) conducted a systematic review and meta-analysis of four studies and found that, among pediatric patients with abdominal pain, POCUS was most useful for ruling in appendicitis in but was unable to rule it out. On the basis of this study, it appears that primary care providers must still acquire consultative ultrasonography to sufficiently rule out appendicitis in the pediatric population; however, the true value of POCUS lies in the ability of primary care providers to evaluate whether the appendix has ruptured since a ruptured appendix predisposes the patient to several complications.

Intussusception is cited as one of the most common abdominal conditions in children, and it often resolves with minimal treatment, but complications such as bowel ischemia or perforation can lead to life-altering surgeries such as colectomy, ileostomy, or peritonitis (Kelley-Quon et al., 2021). Arroyo et al. (2021) studied emergency physicians who used POCUS to determine the presence of intussusception and compared this procedure to consultative ultrasonography. They found that POCUS and consultative ultrasonography had excellent diagnostic agreement for the presence or absence of intussusception (97% of cases; k = 0.826), and there was a sensitivity, specificity, positive predictive value, positive likelihood ratio, and negative likelihood ratio of 89%, 98%, 80%, 40.44, and 0.11, 95% CI [51%, 99%], [92%, 100%], [44%, 96%], [10.07, 162.36], [0.02, 0.72], respectively.

Blunt traumatic injuries, such as falls and their complications, are recognized as one of the leading reasons for pediatric health care visits in Canada, and they are the top reason for hospitalization among children aged 0-14 (Parachute, 2016; Public Health Agency of Canada, 2009). Distal forearm injuries are commonly observed in pediatric patients in these cases because the hand is often outstretched to brace for impact during a fall. Similar to the adult population, there is evidence that POCUS can reliably detect distal forearm fractures in children. In a study of 204 pediatric patients who presented to a single Australian emergency department with non-angulated distal forearm injuries, NPs who used POCUS had a sensitivity and specificity of 94.6% and 85.3%, 95% CI [89.2%, 97.3%], [75.6%, 91.6%], respectively, for the detection of distal forearm fractures (Snelling et al., 2021). These findings are comparable to consultative radiography, which is considered the standard of care for the diagnosis of forearm fractures.

Children also have larger heads relative to their bodies, and for this reason, they are susceptible to head injuries (Bickley et al., 2021). A systematic review and meta-analysis of seven studies of pediatric patients who sustained blunt traumatic head injuries and presented to the emergency department found that, when compared to the CT scan, the diagnostic standard for detecting skull fractures, POCUS had a pooled sensitivity, specificity, positive predictive value, and negative predictive value of 91%, 96%, 88%, and 97%, 95% CI [87%, 94%], [94%, 97%], [84%, 92%], [95%, 98%], respectively, along with an associated false positive rate of 27 and a false negative rate of 20 (Alexandridis et al., 2022). This study suggests POCUS can effectively rule out skull fractures.

Education and Training Standards

The vast spectrum of POCUS applications in primary care is a blessing because patients and health care systems stand to benefit from its versatility. Despite this, there is concern among health care safety advocates, radiologists, and even POCUS advocates that safeguards ensuring that POCUS users have the requisite training, experience, and skill have not kept pace with the speed of adoption. This is of particular concern given that POCUS is operator-dependent (CAR, 2013; Chawla et al., 2019; Cheney, 2019; Conner et al., 2019; Lewis et al., 2018; Micks et al., 2016; Peng et al., 2019). Several medical specialties have addressed these concerns by creating education and training recommendations as well as competencies. The AAFP (2016) has published a POCUS curriculum guideline for prospective programs, and the ACEP (2016) has a policy statement determining training and proficiency guidelines. In Canada, there is little guidance as to the education that a primary care provider requires to operate POCUS, despite 71% of surveyed family medicine program directors agreeing that POCUS is beneficial for primary care (Micks et al., 2018). The Canadian POCUS Society (CPOCUS), formally known as Canadian Emergency Ultrasound, has a dedicated family medicine training certification program which centres on what it considers to be the core POCUS applications (CPOCUS, n.d.-a; n.d.-b), but it is unclear how these education programs and competencies were determined. The Canadian Association of Emergency Physicians has published curriculum guidelines making general recommendations for education and instructional methods, but they are emergency medicine-centric (Lewis et al., 2019).

It is almost certain that NPs are currently operating POCUS in clinical practice; however, there is a paucity of literature describing the education and training that NPs must undertake to competently operate POCUS in clinical practice. Currently, NPs seeking training to operate POCUS must turn to education designed for medical specialties. This seemingly benign issue is problematic, because it represents a failure of the NP profession to properly meet its ethical and legal obligations as well as its professional responsibilities for high-quality and safe patient care.

Ethical Obligations. Bound by their code of ethics, NPs have an ethical obligation to ensure that, when they operate POCUS for patient care, they do so in a safe, compassionate, competent, and ethical manner and they remain accountable for their practice (CNA, 2017; 2019). Failure to meet these ethical obligations is a failure to meet the standards of practice set by their regulatory college (BCCNM, 2021; CNA, 2010; 2017). Finally, their code of ethics highlights their commitment to providing the best care in the safest possible method.

Legal Obligations. The literature gap in NP POCUS education also magnifies a legal concern in the BCCNM NP Scope of Practice document that warrants urgent attention. Section 7.d.1 of the *Nurses (Registered) and Nurse Practitioners Regulation* (2008) indicates that NPs are permitted to perform ultrasound and therefore, by extension, POCUS; however, the BCCNM NP Scope of Practice document has an explicit restriction limiting NPs from taking responsibility for the final interpretation of medical imaging studies in the Ordering Diagnostic Services and Managing Results section (BCCNM, 2021). Given that the images acquired through POCUS are interpreted by the NP without a radiologist, this restriction in the BCCNM NP Scope of Practice document could be interpreted as meaning that NPs cannot legally interpret POCUS images, which would make it almost pointless to use POCUS in NP practice. POCUS experts argue that the device is not meant to replace consultative medical imaging modalities, but rather to answer a specific clinical question that is narrow in scope (Levitz et al., 2016; Lewis et al., 2019; SPOCUS, 2018), and it should therefore be viewed as another tool for bedside patient care akin to a stethoscope (Moore & Copel, 2011; Smallwood & Dachsel, 2018). Thus, the argument can be made that POCUS is actually a procedure or activity that should have its own standards, limits, and conditions under the Advanced Procedures and Activities section of the BCCNM (2021) NP Scope of Practice Document. Regardless, this legal gray area is a priority that could be addressed by creating a specific set of limits and conditions to ensure that all NPs operating POCUS meet the same legal obligations.

Professional Responsibilities. NPs also have a professional responsibility to advance their profession and improve their practice. Embracing POCUS by determining the education required for its competent operation will help NPs stay relevant in the future. Fortunately, NPs are well prepared for this task, as they hold competencies in leadership, health system optimization, education, and research (CNA, 2010; 2019). These competencies allow NPs to take a leadership role in researching their specific educational needs, which would then inform the competencies required to operate POCUS safely. This would maintain safety standards while ensuring that patients and the health system alike can reap its benefits. Currently, many of the standards and competencies for POCUS operation by NPs are based on physician metrics and, while physicians have some practice overlap with NPs, it is unknown whether physician-based standards and competencies are reliable when applied to NP practice given the different philosophical and theoretical underpinnings of the two roles.

NPs have been a disruptive force in BC's health care system since their inception. They provide high-quality patient care and are regarded as changemakers in a system that demands innovation. The evolution of POCUS follows that of NPs, where its introduction into daily patient care has improved the quality of the care delivered and changed how health resources are accessed. This symbiotic relationship between NPs and POCUS is a priority that must be addressed so that NPs can meet their ethical and legal obligations as well as their professional responsibilities.

CHAPTER TWO: INTEGRATIVE REVIEW

This discussion proposed the following question to be answered by this integrative review: What education do nurse practitioners need to competently operate POCUS in BC primary care settings?

Design

The literature search was designed using the Population, Intervention, and Outcome (PIO) framework, which is adapted from the Population, Intervention, Comparator, and Outcome framework commonly used to design research questions (Fineout-Overholt & Johnston, 2005). PIO was chosen as the framework because the intention of this research question was not to compare competencies with other health care providers. The population of interest is NPs who practice in primary care settings; the intervention of interest is the use of POCUS in primary care settings; and the outcome of interest is the education that NPs require to competently operate POCUS.

Search Methods

Databases

Three databases were used for the literature search: The Cumulative Index to Nursing and Allied Health Literature (CINAHL) via the Elton B. Stephens Company (EBSCO), MEDLINE via PubMed, and Web of Science. CINAHL and Web of Science were accessed through the University of Northern British Columbia's online library website, while MEDLINE was accessed through the PubMed website. CINAHL was selected as a database because it is a repository of nursing and allied health journals (Gray et al., 2017) that had the possibility to provide more literature specific to NPs compared to the other databases. MEDLINE was selected for its comprehensive collection of medical, nursing, and health system literature (Gray et al., 2017), and it was believed that POCUS literature would be more widely prevalent in this database. Web of Science is a database that combines the Science Citation Index, the Social Science Citation Index, and the Arts and Humanities Index, as well as indices of conference proceedings (Gray et al., 2017); it was selected because it could search multiple databases and return results that CINAHL or MEDLINE failed to find. Finally, hand searching for clinical practice or education guidelines related to POCUS was conducted via the Google Search engine. Hand searching through reference lists, and custom hand searches in the search engine for articles that were not practice or education guidelines, were not conducted in order to maintain reproducibility.

Search Terms

The search terms were derived from the research question and mind mapping; see Appendix A for a visual representation. Search terms can be found in Table 2.

Table 2

Search Terms

Population	nurse practitioner, nurse practitioner student, general practitioner, family physician, resident, medical student, intern, general practice, family practice, primary care, primary health care
Intervention	point-of-care, ultrasonography, ultrasound, sonography, sonogram
Outcome	education, training, competenc*

Note. The asterisk is a wildcard search function that was used to capture variations of the word "competency."

Boolean operators such as AND and OR were used to group search terms where appropriate. See Appendix B for specific search strings that were used for each database.

Inclusion and Exclusion Criteria

Inclusion and exclusion criteria were chosen to maintain relevance to the proposed integrative review. Results that included licensed NPs, NP students, medical students, family medicine or emergency medicine residents, interns, family physicians, and general practitioners were included to capture literature concerning POCUS education in undergraduate, graduate, and professional development programs in family practice streams of medical or nursing education. The search term “intern” was chosen as this is the title used for resident physicians in their first year of postgraduate training and is occasionally used for medical students in their clinical rotations. Articles discussing POCUS education for emergency medicine were included because of the aforementioned similarities between family medicine and emergency medicine in Canada; studies including emergency medicine in other countries where emergency medicine training is different were included as Canadian emergency physicians may practice in emergency settings in other countries where training routes differ. Studies that did not include family or emergency medicine residents were excluded as non-family or non-emergency medicine practice patterns may not be representative of primary care. Studies that included family or emergency residents with other medical specialties or health care professions in their samples were included to better understand the educational needs of those with primary care practice. The articles included must have identified the POCUS education and training in order to inform the education and training required to be competent. Studies where education and training were based on hospital-based visits, aside from emergency medicine, were excluded because the practice patterns differ from primary care.

In addition to primary sources, secondary sources were included because they might identify themes that would not otherwise be captured in a primary study. Quantitative, qualitative, mixed-methods, narrative, expert-opinion and descriptive studies as well as practice guidelines, curriculum recommendations, and commentary sources were included in order to capture a wide breadth of data. Moreover, it has been suggested that POCUS technology began to match the imaging quality of traditional machines after 2010, and competency training began around the same time (Moore & Copel, 2011; Soni et al., 2020); for this reason, studies published before 2010 were excluded. Records written in languages other than English were excluded because there was no translation service available for the integrative review, and the author only fluently speaks English. A Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart was used to sort articles as they were included and excluded. See Appendix C for the PRISMA flow diagram. The articles were managed in Zotero, an open-source reference management program that facilitates the organization and sorting of bibliographic data.

Data Evaluation

An integrative review of this magnitude has the potential to set a precedent for NP POCUS education; a rigorous evaluation of the quality of the included data was therefore conducted using the Joanna Briggs Institute (JBI; n.d.) and the updated Appraisal of Guidelines, Research, and Evaluation (AGREE II; Browers et al., 2016) critical appraisal tools. The JBI critical appraisal tools were selected for their reputation as global leaders in evidence-based health care. The AGREE II critical appraisal tool was selected for the practice guidelines because it was developed in Canada and is internationally recognized as a valid tool for critical appraisal.

Each article included in this integrative review was appraised using the respective JBI or AGREE II critical appraisal tool, and a score was generated and recorded. Scoring categories that were not applicable to the respective study were not included. The total scores can be found in the literature matrix table in Appendix D. Where certain critical appraisal scoring categories did not apply to a particular article, this was identified. After completing the data evaluation, the data was analyzed.

Data Analysis

The included articles were analyzed in four steps according to the integrative review recommendations from Whittemore and Knafl (2005). First, the articles were divided into quantitative reviews, expert opinions, and clinical practice guidelines. This was done to ensure that themes could be extrapolated systematically from the respective articles. Next, the salient research methodology, sampling, findings, critical appraisal, and relevance were extrapolated and displayed in a literature review matrix to facilitate ease of reference. In the literature review matrix, the data was compared and analyzed to search for recurring themes, patterns, and heterogeneity among the findings. Lastly, conclusions were drawn from the data, and efforts were made to verify the frequency of findings.

CHAPTER THREE: FINDINGS

Guided by the question, "what education do NPs need to competently operate POCUS in primary care?", this integrative literature review found data from several countries and multiple methods of education and training modalities, but there was a lack of data specific to NPs in primary care. This chapter will present the results of the literature search as well as the themes, limitations, and recommendations for education and training programs for NPs to meet their ethical and legal obligations as well as their professional responsibilities related to POCUS operation in primary care.

Search Results

The systematic searches yielded two, 104, 154, and four articles in CINAHL, Web of Science, MEDLINE, and hand searching, respectively. After removing duplicates, a total of 188 articles remained. The article titles and abstracts were screened using the inclusion and exclusion criteria; this excluded 147 articles, leaving 40 articles for eligibility assessment. These articles were read in their entirety and, after applying the inclusion and exclusion criteria, 18 articles were excluded, leaving a total of 22 articles to be included in the final integrative review. Thirteen of these articles were primary studies, three were narrative articles, two were systematic reviews, and four were practice guidelines. No articles were published before 2013. Only 17% of the articles were based in Canada, 43% were from the USA, and the remaining 40% were from geographic settings outside North America.

Thirteen of the articles were quantitative studies, of which 11 were observational studies (Boniface et al., 2019; Bornemann, 2017; Dornhofer et al., 2020; Hall et al., 2021; Kimambo et al., 2021; Lindgaard & Riisgaard, 2017; Safavi et al., 2018; Situ-LaCasse et al., 2021; Snelling et al., 2021; Wong et al., 2013; Yamada et al., 2018), one was a mixed case-control and expert-opinion Delphi study (Homar et al., 2020), and one was a case-control study (Tuvali et al., 2020). Two articles included health care professions other than physicians (Dornhofer et al., 2020; Hall et al., 2021), midwives and clinical officers, specifically, and only one article included NPs (Snellen et al., 2021).

Four clinical practice guidelines were included (AAFP, 2016; ACEP, 2017; Lewis et al., 2018; SPOCUS, 2018). All of the clinical practice guidelines were found through hand searching. Three of the clinical practice guidelines included health care professions other than physicians (ACEP, 2016; Lewis et al., 2018; SPOCUS, 2018).

Two systematic reviews were included, totalling 51 articles and 33 articles, respectively (Andersen et al., 2019; Andersen et al., 2021). The vast majority of the articles informing both systematic reviews were observational studies, with the exception of one single randomized control trial that was included in both systematic reviews. Both systematic reviews only included general practitioners, which were defined as family physicians or family medicine residents.

Three narrative reviews were included in the study. The first was a narrative summary Barron et al. (2019) who summarize one POCUS program's education program, the second article was by Chamsi-Pasha et al. (2017) who describe POCUS echocardiography, and the third article was based on one family medicine resident's POCUS education experience in a Canadian medical school program (Micks et al., 2016).

Three themes emerged from the articles in this integrative review. First, the overall body of literature informing POCUS education and training for primary care was based on observational studies of low to moderate quality, which arguably makes proving causation problematic. Second, optimal POCUS education and training is not yet well understood, and current education and training programs have a wide variety of educational content, modalities, and evaluation methods. Third, POCUS is inclusive and not limited to use by any one health profession or clinical experience; rather, the literature suggests that any health care provider can learn POCUS given access to appropriate education and training.

Wide Spectrum of Methodological Quality

The literature included in this integrative review ranged from low to high quality. The JBI quality scores for the observational cohort studies ranged from 3 to 10 on an 11-point scale (Boniface et al., 2019; Bornemann, 2017; Dornhofer et al., 2020; Hall et al., 2021; Kimambo et al., 2021; Lindgaard & Riisgaard, 2017; Safavi et al., 2018; Situ-LaCasse et al., 2021; Snelling et al., 2021; Wong et al., 2013; Yamada et al., 2018); however, three of the scores were not measured on the 11-point scale, as some point categories were not applicable (Bornemann, 2017; Safavi et al., 2018; Wong et al., 2013). The JBI scores for the text, narrative, and opinion articles ranged from 4 to 6 on a 6-point scale (Barron et al., 2019; Chamsi-Pasha et al., 2017; Micks et al., 2016), and from 3 to 6 on a 10-point scale for the two case control studies (Homar et al., 2020; Truvali et al., 2020); however, not all points were relevant on the 10-point case control scale, as some eligible points were not relevant to the research question. The AGREE II scores ranged from 32 to 55 on an 87-point scale for all four practice guidelines (AAFP, 2018; ACEP, 2016; Lewis et al., 2018; SPOCUS, 2018). Both systematic reviews were of excellent quality, scoring 11 points on an 11-point JBI scale for systematic reviews (Andersen et al., 2019; Andersen et al., 2021).

With respect to methodology, all primary studies included in this integrative review were observational cohort or case control studies with sample sizes ranging from 5 to 116 participants. Participants were recruited through variations of convenience sampling (Boniface et al., 2019; Bornemann, 2017; Dornhofer et al., 2020; Hall et al., 2021; Homar et al., 2020; Kimambo et al., 2021; Lindgaard & Riisgaard, 2017; Safavi et al., 2018; Situ-LaCasse et al., 2021; Snelling et al., 2021; Truvali et al., 2020; Wong et al., 2013; Yamada et al., 2018), and no studies had consecutive enrollment. The populations studied included physicians with some practice patterns related to primary care (Homar et al., 2020; Lindgaard & Riisgaard, 2017; Wong et al., 2013); medical students (Safavi et al., 2018; Situ-Lacasse et al., 2021); assistant and medical clinical officers with practice patterns similar to physicians and NPs (Kimambo et al., 2021); nurses and midwives (Dornhofer et al., 2020; Hall et al., 2021); or some combination of the aforementioned populations (Boniface et al., 2019; Bornemann, 2017; Dornhofer et al., 2020; Hall et al., 2021; Kimambo et al., 2021; Truvali et al., 2020; Yamada et al., 2018). There was only one study that included NPs, which was conducted by Snelling et al. (2021). Eleven of the primary studies included in this integrative review had a POCUS education or training program as their intervention (Boniface et al., 2019; Bornemann, 2017; Dornhofer et al., 2020; Hall et al., 2021; Kimambo et al., 2021; Lindgaard & Riissgaard, 2017; Safavi et al., 2018; Situ-Lacasse et al., 2021; Tuvali et al., 2020; Wong et al., 2013; Yamada et al., 2018). Five articles used pre- and post-test score comparisons to determine curriculum effectiveness (Dornhofer et al., 2020; Hall et al., 2021; Kimambo et al., 2021; Safavi et al., 2018; Situ-Lacasse et al., 2021), two articles compared FPs and NPs with another physician specialty as a marker of POCUS accuracy (Lindgaard & Riisgaard, 2017; Snelling et al., 2021), and one article examined the use of a digital image reviewer in place of a physician to assess the quality of POCUS images (Boniface et al., 2019).

The systematic reviews included in this integrative review sought to describe the practice patterns, prior POCUS learning experience, and educational needs of general practitioners, which were defined as physicians (Andersen et al., 2019; Andersen et al., 2021). Fifty-one and 33 articles were included in the Andersen et al. (2019) and Andersen et al. (2021) systematic reviews, respectively. The vast majority of the studies included in each systematic review were observational, with Andersen et al. (2019) containing two non-observational trials and Andersen et al. (2021) containing one non-observational trial. The systematic reviews included studies from 16 and 20 different countries, respectively (Andersen et al., 2019; Andersen et al., 2021). The authors of each systematic review provided their internal quality score for the included articles. Andersen et al. (2019) had a mean score of 12.5 and Andersen et al. (2021) had a mean score of 11.9, both on a 21-point Downs and Black scale. Only one article out of both systematic reviews included a non-physician (Andersen et al., 2021). NPs were not included in either systematic review.

Four clinical practice guidelines were included in this integrative review: one guideline was specific to family physicians (AAFP, 2016), two were specific to emergency medicine (ACEP, 2016; Lewis et al., 2018), and one was intended for all POCUS users (SPOCUS, 2018). All clinical practice guidelines provided a position statement and specific to non-specific recommendations for POCUS education, training, competency, and clinical uses (AAFP, 2016; ACEP, 2016; Lewis et al., 2018; SPOCUS, 2018); however, no guideline provided literature search details. A review of each practice guideline’s reference list showed a large proportion of references related to emergency medicine literature.

Lasty, the three text, narrative, and opinion articles included a literature summary, recommendations, and future directions of POCUS echocardiography education and training (Barron et al., 2019; Chamsi-Pasha et al., 2017; Micks et al., 2016). One narrative article discussed the experience of one family medicine resident who was able to learn POCUS to provide care in rural practice settings (Micks et al., 2016).

Education and Training Modalities

This integrative literature review found significant heterogeneity in the literature with respect to POCUS education and training. Twenty-one articles described a combination of didactic lectures, online learning modules, hands-on ultrasonography with standardized and/or healthy volunteer patients, direct and indirect ultrasonography supervision, image review, ultrasonography physics, equipment review, formative feedback through indirect and direct supervision of ultrasonography scanning, and summative evaluation through objective, structured ultrasonography scan examination and/or written examinations (AAFP, 2016; ACEP, 2016; Andersen et al., 2019; Andersen et al., 2021; Barron et al., 2019; Boniface et al., 2019; Bornemann, 2017; Chamsi-Pasha et al., 2017; Dornhofer et al., 2020; Hall et al., 2021; Kimambo et al., 2021; Lewis et al., 2018; Lindgaard & Riisgaard, 2017; Micks et al., 2016; Safavi et al., 2018; Situ-Lacasse et al., 2021; Snelling et al., 2021; SPOCUS, 2018; Tuvali et al., 2020; Wong et al., 2013; Yamada et al., 2018). In areas where access to direct supervision was unavailable, Boniface et al. (2019) found that the use of a smartphone-based standardized direct observation tool could adequately provide peer review of remote ultrasonography image quality. One article found that POCUS education and training should involve a degree of clinical examination skills, knowledge, anatomy, probe handling, ultrasonography machine manipulation, and lessons for referral and consultation (Homar et al., 2020); however, the authors do not indicate how the aforementioned education and training should be delivered or ensured.

Among the primary studies and narrative papers included, three articles provided information regarding curricula spanning more than 7 days (Barron et al., 2019; Bornemann, 2017; Hall et al., 2021; Tuvali et al., 2020); this length of time was associated with increased POCUS use (Tuvali et al., 2020), increased test scores (Bornemann, 2017), and more opportunities for professional and academic appointments (Barron et al., 2019). Eight of the primary studies found that POCUS education and training can be achieved in short education and training sessions ranging from two hours to five days (Dornhofer et al., 2020; Kimambo et al., 2021; Lindgaard & Riisgaard, 2017; Safavi et al., 2018; Situ-Lacasse et al., 2021; Snelling et al., 2021; Wong et al., 2013; Yamada et al., 2018). Andersen et al. (2019) found that POCUS education and training among general practitioners ranged from 4 to 320 hours, whereas Andersen et al. (2021) found that education and training sessions ranged from as few as 1 to 30 hours. The AAFP (2016), ACEP (2016), and SPOCUS (2018) guidelines indicate that a minimum of 150 to 300 total scans with an additional 25 to 50 supervised scans for specific diagnostic indications, as well as 5 to 10 supervised scans, are needed to ensure diagnostic and procedural competency. Lewis et al. (2018), the authors of the sole Canadian practice guideline, suggested that 10 to 50 scans on standardized or volunteer patients are required to determine POCUS competency; no other details were provided related to achieving procedural competency. All practice guidelines indicate that external credentialing is optional and that each individual institution granting the privilege to operate POCUS should have clearly defined credentials (AAFP, 2016; ACEP, 2016; Lewis et al., 2018; SPOCUS, 2018).

Opportunity to Learn

The third theme that emerged from this integrative review is that POCUS operation can be taught to and learned by a range of health care professionals, such as NPs, attending and resident physicians across various specialties, medical students, nurses, and midwives (AAFP, 2016; ACEP, 2016; Andersen et al., 2019; Andersen et al., 2021; Barron et al., 2019; Boniface et al., 2019; Bornemann, 2017; Chamsi-Pasha et al., 2017; Dornhofer et al., 2020; Hall et al., 2021; Homar et al., 2020; Lewis et al., 2018; Lindgaard & Riisgaard, 2017; Micks et al., 2016; Safavi et al., 2018; Situ-Lacasse et al., 2021; Snelling et al., 2021; SPOCUS, 2018; Tuvali et al., 2020; Wong et al., 2013; Yamada et al., 2018) as well as clinical officers, who are health care providers who provide emergency and general care in dispensaries or health centres in Tanzania (Kimambo et al., 2021). Furthermore, clinical rank and experience may not necessarily be as significant as time spent learning POCUS as it relates to becoming proficient (Bornemann, 2017; Dornhofer et al., 2020; Hall et al., 2021; Kimambo et al., 2021; Safavi et al., 2018; Situ-Lacasse et al., 2021; Snelling et al., 2021; Yamada et al., 2018); rather, opportunities to enroll in structured education and training programs are likely to increase POCUS confidence, use, and competency (AAFP, 2016; ACEP, 2016; Andersen et al., 2019; Andersen et al., 2021; Barron et al., 2019; Bornemann, 2017; SPOCUS, 2018; Tuvali et al., 2020). Traditionally viewed as a physician-specific device, Dornhofer et al. (2020) found that, given the same curriculum and education opportunities, a greater percentage of nurses passed the post-course test examination compared to physicians. Studies related to POCUS education programs for health professions other than physicians were in developing countries (Dornhofer et al., 2020; Hall et al., 2021; Kimambo et al., 2021), which can limit generalizability to Canadian settings where education, licensing, and credentialing could be significantly different.

CHAPTER FOUR: DISCUSSION

This integrative review sought to determine the education that NPs need to competently operate POCUS in BC primary care settings. Identifying the educational needs related to POCUS is a priority, because NPs have an ethical and legal obligation as well as a professional responsibility to their patients, their regulatory college, and their profession to ensure patient safety while reaping the benefits of the more accurate diagnosis, safer clinical procedures, and improved health care access associated with POCUS. Despite this systematic search, there was only one result specific to NPs, meaning that the data informing NP POCUS education needs will require extrapolating from existing POCUS programs, which are primarily geared toward medical practitioners.

Problematic Generalizability

The research findings form the basis of the recommendations; unfortunately, all of the primary articles included in this integrative review suffered from a degree of sampling bias and suboptimal methodology, which made it problematic to generalize the results, themes, and conclusions to NP POCUS education needs. First, all of the primary articles recruited patients through convenience sampling methods, and participants were not enrolled consecutively (Barron et al., 2019; Bhoi et al., 2013; Boniface et al., 2019; Bornemann, 2017; Dornhofer et al., 2020; Hall et al., 2021; Homar et al., 2020; Kimambo et al., 2021; Lindgaard & Riisgaard, 2017; Safavi et al., 2018; Situ-LaCasse et al., 2021; Snelling et al., 2021; Truvali et al., 2020; Wong et al., 2013; Yamada et al., 2018). Convenience sampling is subject to selection bias (Davis & Logan, 2018); this method of selecting participants for studies can be influenced by internal or external factors, resulting in biased results. The most striking example of selection bias was in Hall et al. (2021), where the participants who enrolled in the POCUS education programs were chosen by the government's ministry of health. Andersen et al. (2019) and Andersen et al. (2021) also found similar convenience sampling methods in their respective systematic reviews. Moreover, seven of the primary articles had sample sizes of less than 20; these small sample sizes have the potential to over- or under-exaggerate their findings (Bornemann, 2017; Hall et al., 2017; Homar et al., 2020; Kimambo et al., 2021; Lindgaard & Riisgaard, 2017; Snelling et al., 2021; Wong et al., 2013). Another issue with the sampling methods was the fact that consecutive enrollment was either absent or not discussed in all the primary articles included in this integrative review. Consecutive enrollment of participants can reduce selection bias because it helps to decrease the chances of selecting participants with characteristics that are favourable to the hypothesis of the study. The cumulative effect of selection bias, small sample sizes, and questionable consecutive enrollment makes generalizing the research findings and recommendations to NP POCUS education needs uncertain, as the data may not accurately represent the true nature of learner characteristics and education needs. The need to accurately understand NP education requirements is a priority because the foundational training for NPs differs from that of other health professions.

Secondly, all of the primary studies and the vast majority of the references included in the systematic reviews and practice guidelines discussed in this integrative literature review were observational studies, which makes causation difficult to infer. While the benefits of observational trials may provide correlations or associations, the very nature of this type of study design makes it difficult to prove causation because of the inability to control for variables (Stovitz & Schrier, 2019). Coupled with the fact that NPs are underrepresented in the studies and that the overall samples themselves are heterogeneous in this integrative literature review, drawing conclusions based on these studies may lead to erroneous or inappropriate recommendations.

Point-of-Care Ultrasonography Education Is in Its Infancy

The AAFP (2016), ACEP (2016), Lewis et al. (2018), and SPOCUS (2018) practice guidelines make recommendations regarding the components that should be included in any prospective or existing POCUS education program, and the Andersen et al. (2019) and Andersen et al. (2021) systematic reviews focus on describing which POCUS uses should be considered within the scope of practice. The primary articles described education programs that ranged in duration from single-day to months-long programs and used various measurements to determine competency. Education programs included didactic lectures, reviews of relevant anatomy and physiology, ultrasound physics, device manipulation, and hands-on practice. Many of the education programs described the successful completion of a summative assessment, either in the form of a written test or an objective, structured evaluation of hands-on application on a pre-defined date, usually at the end of the education program, as the marker of competency; however, there was no agreement on which components should make up these summative assessments or how they should be tested.

It is important to note that the education programs described in this integrative literature review were designed by physicians for physicians and thus assume that the participant has a foundation in medical education. In the studies that included NPs, nurses, midwives, or clinical officers as attendees, they were enrolled in a curriculum that had been tailored to physicians. While the type of POCUS educational content concerning how to use the POCUS machine should be universal, the education regarding clinical application of the POCUS images may differ for health professions not trained in the medical model. The emphasis allocated to each individual component in the described educational programs assumes that the learner has epistemological foundations in medical education. For example, medical training contains a degree of formal diagnostic image interpretation, whereas foundational and advanced nursing education rarely, if ever, include a component of formal diagnostic image interpretation. Conversely, NPs have extensive education and regulatory standards of practice regarding documentation and the communication of findings to patients. With respect to POCUS education programs, therefore, NPs would need less time allocated to POCUS documentation and communication with patients but more time dedicated to image interpretation.

While successfully completing a test or examination is common practice among NP education programs and even for NP licensure, it is unclear whether successfully completing a POCUS test or examination is a predictor of ongoing competency in POCUS use and interpretation, which is arguably a more important metric to understand. Indeed, POCUS is an operator-dependent process that can cause significant harm to patients if inappropriately integrated into patient care. The results of this integrative literature review do not make it possible to conclude that longitudinal POCUS quality assurance is superior or comparable to a one-time assessment; however, it is likely reasonable to assume that education in the form of the periodic objective evaluation of POCUS operation by NPs would support ongoing competency. ACEP (2016) and SPOCUS (2018) state that external certification is not universally recommended; rather, peer review or internal quality assurance programs specific to the needs and practice patterns of NPs may be superior to external certification.

The findings from this integrative review suggest that POCUS can be used effectively by many health care professions and that, with appropriate education and training, NPs and other health care professions can competently operate POCUS. It was shown in Indonesia and

Zanzibar that nurses, midwives, and physicians can learn POCUS in short training courses (Dornhofer et al., 2020) as well as longitudinal programs (Hall et al., 2021); these findings are similar to those of medical students (Safavi et al., 2018; Situ-Lacasse et al., 2021) and attending or resident physicians acquiring competency in POCUS through traditional education programs (Barron et al., 2019; Bornemann, 2017). While it remains unclear what education and for what duration this education should be, NPs must make POCUS education a priority as the potential benefit for patient care cannot be ignored.

Implications for Nurse Practitioners in British Columbia

This integrative review found that education modalities for POCUS vary widely, that the existing body of literature informing competency is heterogeneous among medical providers, and that data specific to NPs does not yet exist. The absence of data, however, has several implications for NPs, particularly surrounding opportunities to fully realize their scope of practice, define an aspect of their professional identity, determine their practice and educational needs, and shape the future of NP practice in BC primary care settings.

Increase the Quantity and Quality of Research

The paucity of NP-specific data suggests that POCUS education for NPs is largely unknown and, in the interests of patient safety and meeting legal obligations, the urgency of research into NP POCUS education is a priority. NPs should engage NP leaders, educators, and changemakers to improve the quantity and quality of NP POCUS data through three mechanisms.

First, the CNA (2016) recommended that the quality of the NP workforce and education data at the CIHI should be enhanced. Doing so would allow for an understanding of the current landscape of NP POCUS education needs, practice patterns, and initial and ongoing competency education requirements. The easiest method would be to calculate the number of NPs who have applied for POCUS privileges from the BCMQI privileging database, then determine how these NPs acquired their POCUS competencies and how they were initially credentialled.

Secondly, at the CNA NP roundtable in November 2015, NPs from across Canada emphasized that they have very little opportunity to fulfill their advanced practice competencies beyond clinical care due to practice arrangements or employment conditions (CNA, 2016). The Nurses and Nurse Practitioners of BC, a professional organization tasked with representing the interests of NPs in BC, should submit a formal request to the BC Ministry of Health to legislate protected time so that NP POCUS leaders can use their full complement of competencies to research and provide guidance on POCUS education needs. These NP POCUS leaders could be identified through the BCMQI privileging database and subsequently could be engaged to research how NPs acquire POCUS education, what they require for this education, and advice for change.

Leverage the Full Complement of Competencies

Perhaps one of the most intriguing findings from this integrative literature review is the inclusivity of POCUS as it relates to practice specialties and health disciplines. It was consistently found that, despite one's clinical rank or health profession, if given access to resources and the opportunity to learn, one can acquire the skills to effectively operate POCUS. NPs should leverage the inclusive nature of POCUS by leading a comprehensive, interprofessional POCUS education program for all health care providers interested in enhancing their practice with POCUS. This would be advantageous for NPs for two reasons. First, acting as the leader in developing a POCUS education program would likely yield valuable information regarding the education needs of all health care providers learning POCUS, which could also serve as the foundation of what NPs require. Second, leading a change in how POCUS education can be viewed as a natural extension of the NP scope of practice, as NPs are collaborative by training and hold competencies in education, research, and knowledge translation. Furthermore, an added bonus of leading an interprofessional POCUS education program is that NPs would be able to determine the education that they need to competently operate POCUS. By leveraging their full complement of competencies to improve POCUS education, NPs address their professional responsibility to advance the profession but also meet their ethical obligations to their patients by ensuring equitable access to safe, comprehensive technology.

Capitalizing on the Current Sociopolitical and Economic Climate

This integrative review was conducted at a time when the sociopolitical and economic climate in BC was advantageous for NPs. As mentioned previously, public and governmental interest in NPs has dramatically increased, and NPs are increasingly viewed as a key resource in solving access gaps across the health care system. Moreover, interest in standardized POCUS education programs to ensure patient safety has increased among POCUS users and patient safety advocates alike. NPs should take advantage of this opportunity to further integrate collaboration among health care providers and to entrench their roles even more fully into the health care system.

Limitations

This integrative review is not without its limitations. First, many of the articles discussed are based on medical education, and NPs are only included in one of the 22 articles. This underrepresentation of NPs makes translating a respective article's findings problematic, as the educational needs and role specifics of NPs are not well represented.

Next, the population search terms may have been suboptimal with respect to capturing the complete breadth of education programs for NPs or physicians. It may have been more advantageous to search for the term nurse practitioner combined with the Boolean operator AND along with family physician or general practitioner or resident or medical student or intern to yield more search results separated into medical education and nursing education. Moreover, POCUS has various synonyms in the literature; search terms such as clinical ultrasound, emergency ultrasound, or bedside ultrasound may therefore provide more relevant literature that could have contributed to this integrative review.

Third, hand searching in the Google search engine was conducted to find relevant POCUS education and practice guidelines but doing so is a potential source of article selection bias. Furthermore, given the scarcity of POCUS literature specific to NPs, it would have been reasonable to conduct hand searching of the article reference lists because it could have yielded articles not yet indexed in the CINAHL, Web of Science, or MEDLINE databases.

CONCLUSION

An integrative literature review was conducted and found a minimal amount of literature specific to the POCUS education needs of NPs. It also found that much of what is known about POCUS education and competency must be generalized from medical education which is problematic given the differences in NP and medical education. In order to meet their ethical and legal obligations and professional responsibilities for safe, high-quality patient care, NPs must leverage their full complement of competencies to determine their education needs in order to fully integrate POCUS into their practice. More research into NP POCUS education should be considered a priority.

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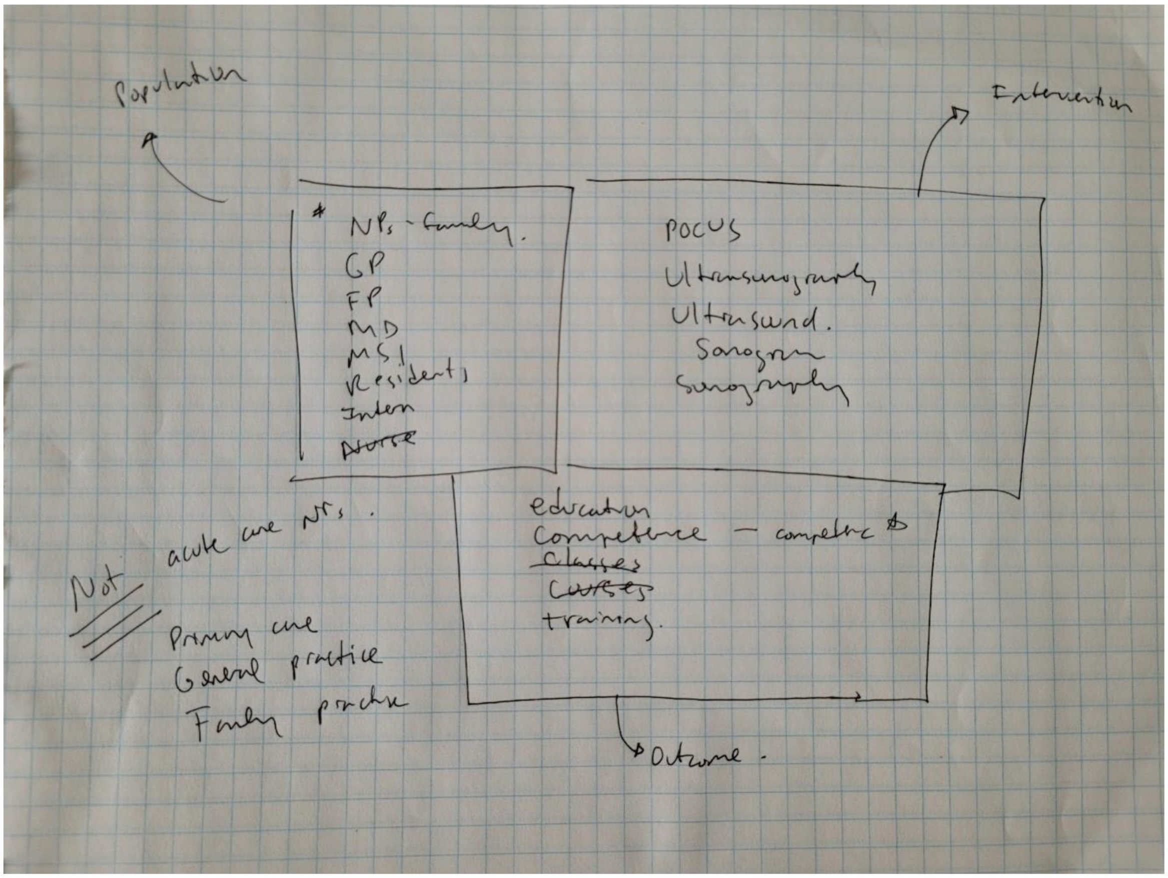
APPENDIX A

Mind Map

Figure 3

Mind Map



Note. This mind map demonstrates a brainstorm of search terms.

APPENDIX B

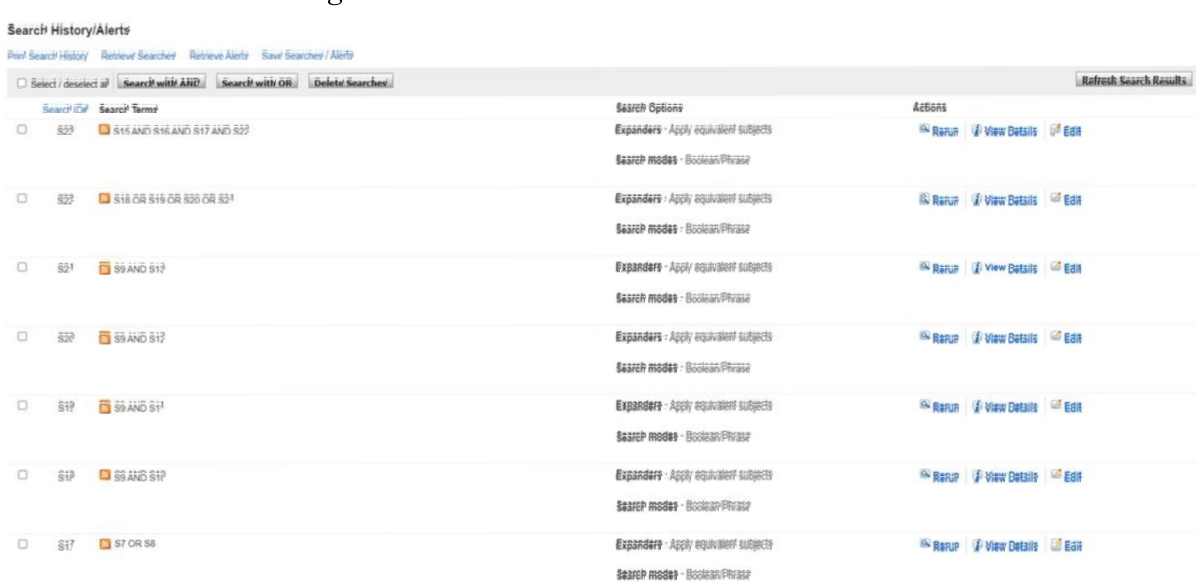
Search Terms

CINAHL

The CINAHL search was conducted on December 18, 2021. The results from search history S23 were included for this literature search. Search terms included nurse practitioner OR nurse practitioner student OR general practitioner OR family physician OR resident OR medical student OR intern AND general practice OR family practice OR primary care OR primary health care AND point-of-care AND ultrasonography OR ultrasound OR sonography OR sonogram AND education OR training OR competenc*. CINAHL auto-populated major heading suggestions after the aforementioned search terms, and these major heading search suggestions were used to acquire the results. It should be noted that the CINAHL search results that included the search terms *education* or *competenc** in combination with the above search terms yielded zero results and were therefore removed from the search string.

Figure 4

Cumulative Index to Nursing and Allied Health Literature Search



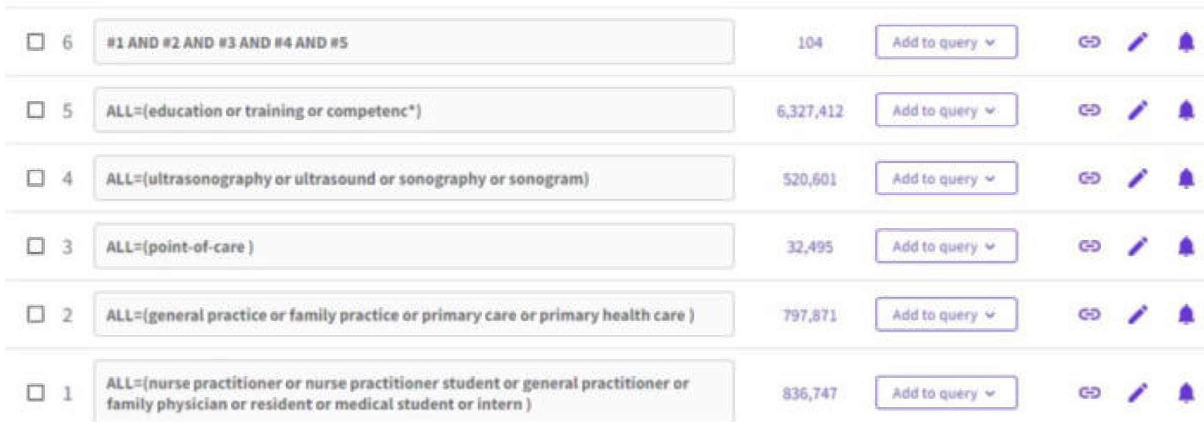
☐	S16	S5 OR S6	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Rerun | View Details | Edit
☐	S15	S4 OR S14	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Rerun | View Details | Edit
☐	S14	S1 OR S2	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Rerun | View Details | Edit
☐	S13	"sonogram"	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Rerun | View Details | Edit
☐	S12	"sonography"	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Rerun | View Details | Edit
☐	S11	"ultrasound"	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Rerun | View Details | Edit
☐	S10	(MH "Ultrasonography")	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Rerun | View Details | Edit
☐	S9	point-of-care	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Rerun | View Details | Edit
☐	S8	"competenc*"	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Rerun | View Details | Edit
☐	S7	(MH "Education")	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Rerun | View Details | Edit
☐	S6	(MH "Primary Health Care")	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Rerun | View Details | Edit
☐	S5	(MH "Family Practice")	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Rerun | View Details | Edit
☐	S4	(MH "Interns and Residents")	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Rerun | View Details | Edit
☐	S3	(MH "Physicians, Family")	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Rerun | View Details | Edit
☐	S2	(MH "Physicians, Family")	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Rerun | View Details | Edit
☐	S1	(MH "Family Nurse Practitioners")	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Rerun | View Details | Edit

Web of Science

The Web of Science search was conducted on December 18, 2021. The following search terms were used in Web of Science: nurse practitioner, nurse practitioner student, general practitioner, family physician, resident, medical student, intern, general practice, family practice, primary care, primary health care, point-of-care, ultrasonography, ultrasound, sonography, sonogram, education, training, and competenc*. Boolean operators were used to combine these search terms. Abstracts were searched primarily as title and subject categories, resulting in hundreds of thousands of results. Results from Set 6 were used for this literature search.

Figure 5

Web of Science Search



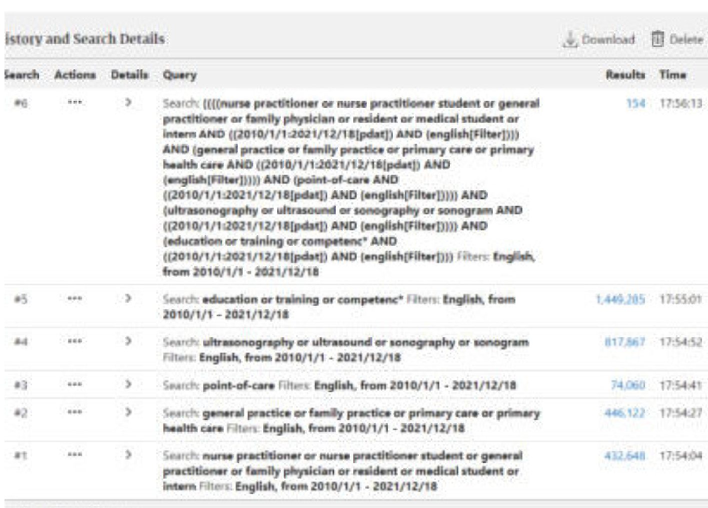
6	#1 AND #2 AND #3 AND #4 AND #5	104	Add to query
5	ALL=(education or training or competenc*)	6,327,412	Add to query
4	ALL=(ultrasonography or ultrasound or sonography or sonogram)	520,601	Add to query
3	ALL=(point-of-care)	32,495	Add to query
2	ALL=(general practice or family practice or primary care or primary health care)	797,871	Add to query
1	ALL=(nurse practitioner or nurse practitioner student or general practitioner or family physician or resident or medical student or intern)	836,747	Add to query

MEDLINE via PubMed

MEDLINE via PubMed was searched on December 18, 2021. Search terms and their medical subject headings were used in conjunction with Boolean operators as shown below.

Figure 6

MEDLINE Search



istory and Search Details

Download Delete

Search	Actions	Details	Query	Results	Time
#6	•••	>	Search: ((((nurse practitioner or nurse practitioner student or general practitioner or family physician or resident or medical student or intern AND ((2010/1/1:2021/12/18[pdat]) AND (english[Filter]))) AND (general practice or family practice or primary care or primary health care AND ((2010/1/1:2021/12/18[pdat]) AND (english[Filter])))) AND (point-of-care AND ((2010/1/1:2021/12/18[pdat]) AND (english[Filter])))) AND (ultrasonography or ultrasound or sonography or sonogram AND ((2010/1/1:2021/12/18[pdat]) AND (english[Filter])))) AND (education or training or competenc* AND ((2010/1/1:2021/12/18[pdat]) AND (english[Filter]))) Filters: English, from 2010/1/1 - 2021/12/18	154	17:56:13
#5	•••	>	Search: education or training or competenc* Filters: English, from 2010/1/1 - 2021/12/18	1,449,205	17:55:01
#4	•••	>	Search: ultrasonography or ultrasound or sonography or sonogram Filters: English, from 2010/1/1 - 2021/12/18	817,867	17:54:52
#3	•••	>	Search: point-of-care Filters: English, from 2010/1/1 - 2021/12/18	74,060	17:54:41
#2	•••	>	Search: general practice or family practice or primary care or primary health care Filters: English, from 2010/1/1 - 2021/12/18	446,122	17:54:27
#1	•••	>	Search: nurse practitioner or nurse practitioner student or general practitioner or family physician or resident or medical student or intern Filters: English, from 2010/1/1 - 2021/12/18	432,648	17:54:04

owing 1 to 6 of 6 entries

#6 ... ˅ Search: ((((**nurse practitioner or nurse practitioner student or general practitioner or family physician or resident or medical student or intern AND ((2010/1/1:2021/12/18[pdat]) AND (english[Filter]))) AND (general practice or family practice or primary care or primary health care AND ((2010/1/1:2021/12/18[pdat]) AND (english[Filter])))) AND (point-of-care AND ((2010/1/1:2021/12/18[pdat]) AND (english[Filter])))) AND (ultrasonography or ultrasound or sonography or sonogram AND ((2010/1/1:2021/12/18[pdat]) AND (english[Filter])))) AND (education or training or competenc* AND ((2010/1/1:2021/12/18[pdat]) AND (english[Filter])))** Filters: **English, from 2010/1/1 - 2021/12/18** 154 17:56:13

(("nurse practitioners"[MeSH Terms] OR ("nurse"[All Fields] AND "practitioners"[All Fields]) OR "nurse practitioners"[All Fields] OR ("nurse"[All Fields] AND "practitioner"[All Fields]) OR "nurse practitioner"[All Fields] OR (("nurse practitioners"[MeSH Terms] OR ("nurse"[All Fields] AND "practitioners"[All Fields]) OR "nurse practitioners"[All Fields] OR ("nurse"[All Fields] AND "practitioner"[All Fields]) OR "nurse practitioner"[All Fields]) AND ("student s"[All Fields] OR "students"[MeSH Terms] OR "students"[All Fields] OR "student"[All Fields] OR "students s"[All Fields])) OR ("general practitioners"[MeSH Terms] OR ("general"[All Fields] AND "practitioners"[All Fields]) OR "general practitioners"[All Fields] OR ("general"[All Fields] AND "practitioner"[All Fields]) OR "general practitioner"[All Fields]) OR ("physicians, family"[MeSH Terms] OR ("physicians"[All Fields] AND "family"[All Fields]) OR "family physicians"[All Fields] OR ("family"[All Fields] AND "physician"[All Fields]) OR "family physician"[All Fields]) OR ("internship and residency"[MeSH Terms] OR ("internship"[All Fields] AND "residency"[All Fields]) OR "internship and residency"[All Fields] OR "residencies"[All Fields] OR "residency"[All Fields] OR "reside"[All Fields] OR "resided"[All Fields] OR "residence"[All Fields] OR "residence s"[All Fields] OR "residences"[All Fields] OR "residency s"[All Fields] OR "resident"[All Fields] OR "resident s"[All Fields] OR "residents"[All Fields] OR "resides"[All Fields] OR "residing"[All Fields]) OR ("students, medical"[MeSH Terms] OR ("students"[All Fields] AND "medical"[All Fields]) OR "medical students"[All Fields] OR ("medical"[All Fields] AND "student"[All Fields]) OR "medical student"[All Fields]) OR ("intern"[All Fields] OR "intern s"[All Fields] OR "internes"[All Fields] OR "interning"[All Fields] OR "interns"[All Fields])) AND (2010/01/01:2021/12/18[Date - Publication] AND "english"[Language]) AND (("general practice"[MeSH Terms] OR ("general"[All Fields] AND "practice"[All Fields]) OR "general practice"[All Fields] OR ("family practice"[MeSH Terms] OR ("family"[All Fields] AND "practice"[All Fields]) OR "family practice"[All Fields]) OR ("primary health care"[MeSH Terms] OR ("primary"[All Fields] AND "health"[All Fields] AND "care"[All Fields]) OR "primary health care"[All Fields] OR ("primary"[All Fields] AND "care"[All Fields]) OR "primary care"[All Fields]) OR ("primary health care"[MeSH Terms] OR ("primary"[All Fields] AND "health"[All Fields] AND "care"[All Fields]) OR "primary health care"[All Fields])) AND (2010/01/01:2021/12/18[Date - Publication] AND "english"[Language])) AND (("point of care systems"[MeSH Terms] OR ("point of care"[All Fields] AND "systems"[All Fields]) OR "point of care systems"[All Fields] OR ("point"[All Fields] AND "care"[All Fields]) OR "point of care"[All Fields]) AND (2010/01/01:2021/12/18[Date - Publication] AND "english"

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Translations

nurse practitioner: "nurse practitioners"[MeSH Terms] OR ("nurse"[All Fields] AND "practitioners"[All Fields]) OR "nurse practitioners"[All Fields] OR ("nurse"[All Fields] AND "practitioner"[All Fields]) OR "nurse practitioner"[All Fields]
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general practitioner: "general practitioners"[MeSH Terms] OR ("general"[All Fields] AND "practitioners"[All Fields]) OR "general practitioners"[All Fields] OR ("general"[All Fields] AND "practitioner"[All Fields]) OR "general practitioner"[All Fields]
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("medical"[All Fields] AND "student"[All Fields]) OR "medical student"[All Fields]
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english[Filter]: english [LA]

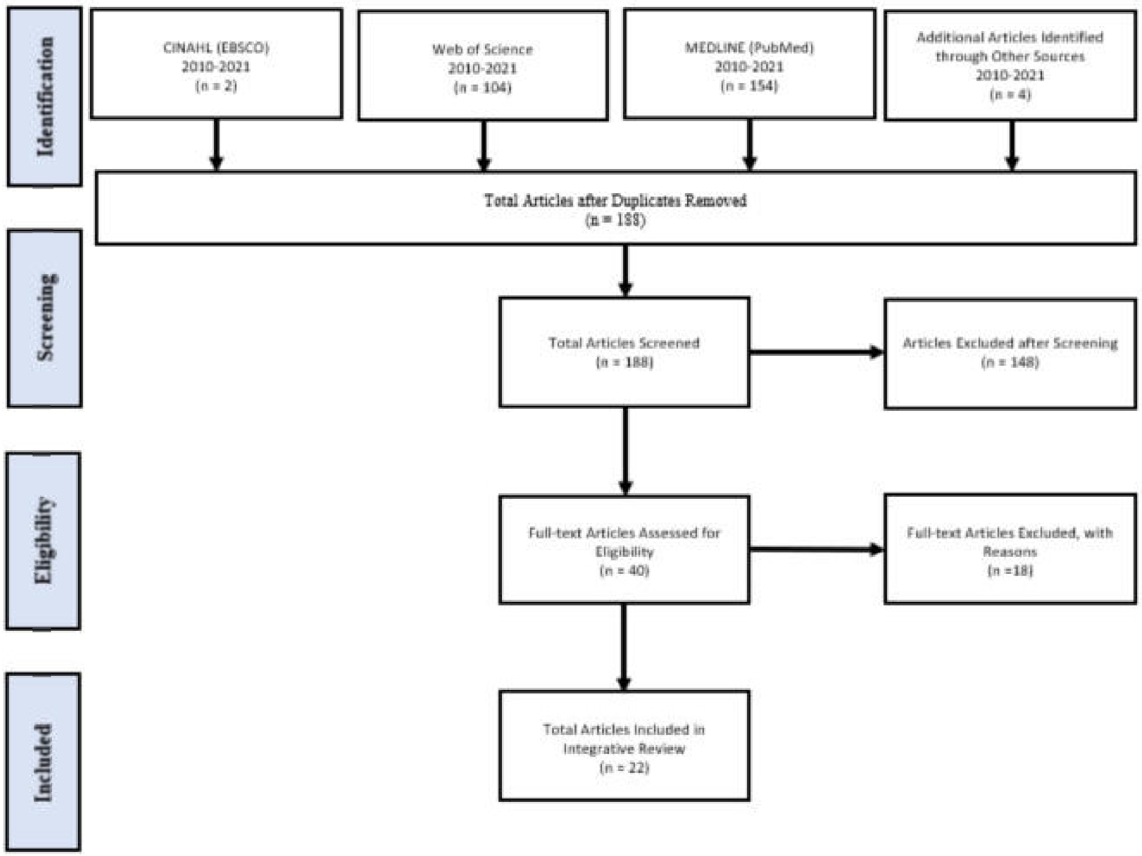
Google Search Engine

Searches were conducted in the Google search engine on December 18, 2021, which yielded four articles. The following search terms were used: nurse practitioner OR nurse practitioner student OR general practitioner OR family physician OR resident OR medical student OR intern AND general practice OR family practice OR primary care OR primary health care AND point-of-care AND ultrasonography OR ultrasound OR sonography OR sonogram AND education OR training OR competenc*.

APPENDIX C

Preferred Reporting Items for Systematic Reviews and Meta-Analyses Flow Diagram

The PRISMA flow diagram below presents the search strategy and the studies identified for a prospective integrative review.



Note. The PRISMA flow diagram is adapted from Moher et al. (2009).

APPENDIX D

Literature Review Matrix

Quantitative and Systematic Review Articles

Author, Title, Journal	Research Objective	Research Methodology	Sample	Findings	Strengths and Weaknesses	Relevance to Capstone
Andersen, C. A., Hedegard, H. S., Lokkegaard, T., Frolund, J., & Jensen, M. B. (2021). Education of general practitioners in the use of point-of-care ultrasonography: A systematic review. *Family Practice,* cmaa140.	Provides a review of POCUS education programs structure, how education is delivered, and how the technical skills of the participants are assessed.	• Systematic review was conducted according to the Cochrane recommendations. • Builds upon a previous systematic review. • MEDLINE via PubMed, EMBASE via OVID, Cumulative Index to Nursing and Allied Health Literature (CINAHL) via EBSCO, Web of Science, and Cochrane Central Register of Controlled Trials databases were searched. • No year or type of publication restrictions. • Keywords: *Ultrasonography*	• 33 articles in total were included in this study. • 31 articles are observational studies; 2 articles are randomized controlled trials. • Seven articles were published before 2003; 25 articles were published after 2012; it is unclear when the remaining study was published. • Methodological quality of the included studies had a mean Downs and Black score of 12.5 out of 21 (low).	• 15 articles used educational programs intended for non-family practice physicians as POCUS training for GPs. • Four articles used canned curriculum from ultrasound societies or other course providers. • Nine articles described a GP POCUS training program but details of the program are unclear as there were no references to a national or residency training program. • All articles featured the teaching of a wide variety of POCUS applications, ranging from specific organ assessment to broad application. • There was wide variation in regard to the time spent in both theoretical and practical training as well as the	**Strengths** • Explores an important literature gap. • Focused on in primary care practice. • Methodology is transparent and there are comprehensive supplementary appendices available for reference. • Findings are in keeping with other literature that a combination of theoretical and practical education is required to operate POCUS. **Weaknesses** • Primary population of study was GPs and GP trainees, who have different	• Describes the current landscape of training to acquire POCUS competency in primary care and general practice. • Confirms there is a gap in the consensus for GP POCUS training and highlights the need to address this gap. • NPs, who are trained differently, have the potential to identify other POCUS education and competencies that could inform future POCUS related education programs.

Author, Title, Journal	Research Objective	Research Methodology	Sample	Findings	Strengths and Weaknesses	Relevance to Capstone
		and *general practice*; all search terms are included in a supplementary index. • Studies eligible for review describe POCUS use among general practitioners (GPs) or general practitioner trainees. ○ GPs were defined as primary care doctors specializing in family medicine, and GP trainees were defined as medical doctors or residents working toward specialization in family medicine. • Studies were excluded if they described thermal therapeutic ultrasound or ultrasound without the production of an		duration of the training programs (1-30 hours) • 27 articles described didactic theoretical teaching. • POCUS instructors ranged from medical students to ultrasound experts, equipment manufacturers, and specialist physicians. • 14 articles described longitudinal practical training achieved via supervision during patient encounters in both primary and acute care settings. • The number of supervised POCUS scans ranged from 5 to 78 ultrasound examinations. • Eight studies described a combination of self-study practice and instructor-led teaching. • 20 articles described using an assessment tool to measure the POCUS competency of the participants; there was wide variation. These included written tests, practical tests, and objective structured competency examination	training than NPs; makes generalizability problematic. • This systematic review builds upon a previous systematic review published by the same primary investigator which could subject this current article to momentum bias; findings from the first systematic review could bias the results in this current article. **Data Analysis** • JBI critical appraisal checklist for systematic reviews score: 11/11.	

Author, Title, Journal	Research Objective	Research Methodology	Sample	Findings	Strengths and Weaknesses	Relevance to Capstone
		image for the clinician to view. • Studies not published in Danish, English, Norwegian, or Swedish were excluded. • A PRISMA flow diagram is included detailing vetting, inclusion, and exclusion of articles.		(OSCE)-style assessments. • There was no association between hours of training, number of performed scans, and diagnostic accuracy. • The ability to rule out a pathology with POCUS seemed to improve with focused practical training.		
Andersen, C. A., Holden, S., Vela, J., Rathleff, M. S., & Jensen, M. B. (2019). Point-of-care ultrasound in general practice: A systematic review. *Annals of Family Medicine, 17*(1).	• To identify: ○ The medical indications for which POCUS was used. ○ POCUS training for GPs. ○ Quality of the scans performed, frequency of use, time required, potential harms, patient satisfaction, and financial costs associated with POCUS used by GPs in	• Systematic review follows the PRISMA guidelines. • Databases searched included MEDLINE via PubMed, EMBASE via OVID, CINAHL via EBSCO, Web of Science, and Cochrane Central Register of Controlled Trials. ▪ Keywords were *ultrasonography* and *general practice* as well as synonyms and MeSH terms, all of which can be	• 51 articles were included after screening and application of inclusion and exclusion criteria. ○ A literature review matrix is available. ○ 16 articles from the United States of America. ○ 10 articles from Norway. ○ Remaining 25 articles were spread across 16 countries. ○ 1 randomized controlled trial,	The most common uses and training programs for POCUS use are: • **Echocardiogram** ○ Focused examination: 8 articles. ○ Full examination: 3 articles. ○ Lectures: 5 articles. ○ Hands-on learning: 6 articles. ○ e-Learning: 2 articles. ○ Case review: 2 articles. ○ Supervised scans: 2 articles. ○ Hospital training: 2 articles. • **Lung** ○ Focused examination: 4 articles.	**Strengths** • Addresses important clinical questions and training issues related to POCUS for general practitioners. • Transparent methodology. • Reported the impact on patient perceptions of POCUS. **Weaknesses** • Multiple research objectives make findings less precise due to sample heterogeneity.	• Provides quantitative data for select POCUS training examinations. • Focuses on the relevant patient population in general practice, which signals the type of POCUS education and competencies required for general practice. • Confirms the overall body of literature regarding POCUS in general practice is limited, but

Author, Title, Journal	Research Objective	Research Methodology	Sample	Findings	Strengths and Weaknesses	Relevance to Capstone
	practice or in training.	cross-referenced in a supplementary index ▪ No restrictions on year of publication, publication type, setting, or patient population. • A modified Downs and Black checklist was used to assess the quality of the articles; results can be found in the supplementary index. Mean score is 11.9 points out of 21 (higher score equates to higher quality). • Only articles in Danish, English, Norwegian, or Swedish languages were included. • Two reviewers independently screen articles in two different phases. ○ A third reviewer was invited to help	50 observational trials. ○ 31 articles are prospective, 19 articles are retrospective, 1 article is a case study. ○ 7 articles included GPs in addition other medical specialties. • Sample inclusion criteria consist of general practitioners, which were defined as medical doctors working in hospitals or outpatient settings as general practitioners, family physicians, primary care doctors, or postgraduate medical doctors working as residents in the field of family medicine.	○ Diagnostic examination: 4 articles. ○ Lectures: 2 articles. ○ Hands-on learning: 2 articles. ○ e-Learning: 1 article. ○ Case review: 1 article. ○ Supervised scans: 1 article. ○ Hospital training: 1 article. • **Aorta** ○ Focused examination: 11 articles. ○ Full examination: 1 article. ○ Lectures: 7 articles. ○ Hands-on learning: 6 articles. ○ e-Learning: 3 articles. ○ Case review: 3 articles. ○ Supervised scans: 6 articles. ○ Hospital training: 3 articles. • **Abdomen** ○ Focused examination: 16 articles. ○ Full examination: 3 articles. ○ Unclear examination: 3 articles. ○ Diagnostic purpose: 18 articles. ○ Screening purposes: 6 articles.	• Limits the generalizability of the study findings to making due to sample heterogeneity. • Sample inclusion criteria were very strictly limited to general practitioners defined as medical physicians; however, one study included a midwife.. • Many included studies have small sample sizes, which may exaggerate or under-exaggerate findings and weaken external validity. • Authors were unable to aggregate data because of the wide range of outcome measures and quality indicators. **Data Analysis**	also indicates that the literature is emerging, suggesting a need for NPs in primary care to define their education needs. • There is quantitative data specific to resource-limited settings.

Author, Title, Journal	Research Objective	Research Methodology	Sample	Findings	Strengths and Weaknesses	Relevance to Capstone
		achieve consensus on article inclusion in the event of disagreement. • The Cochrane data extraction form was used to extract and assess quality; his form can be found in the supplementary index. • Inconsistencies in data extraction were resolved through discussions with two extra reviewers. • Authors expected the results to be of significant heterogeneity and thus pre-emptively decided to synthesize the results in a narrative format. • Articles describing referral for any ultrasound or ultrasound without production of an image for the		○ Lectures: 6 articles. ○ Hands-on learning: 6 articles. ○ e-Learning: 1 article. ○ Case review: 2 articles. ○ Supervised scans: 4 articles. ○ Hospital training: 4 articles. • **Gynecological or Obstetrical** ○ Focused examination: 11 articles. ○ Full examination: 7 articles. ○ Unclear examination: 7 articles. ○ Diagnostic purposes: 23 articles. ○ Screening purposes: 6 articles. ○ Lectures: 9 articles. ○ Hands-on learning: 9 articles. ○ e-Learning: 2 articles. ○ Case review: 3 articles. ○ Supervised scans: 7 articles. ○ Hospital training: 8 articles. • **Musculoskeletal** ○ Focused examination: 3 articles. ○ Full examination: 1 article.	• JBI critical appraisal checklist for systematic reviews score: 11/11.	

Author, Title, Journal	Research Objective	Research Methodology	Sample	Findings	Strengths and Weaknesses	Relevance to Capstone
		clinician to view were excluded.		○ Unclear examination: 1 article. ○ Diagnostic purpose: 5 articles. ○ Lectures: 1 article. ○ Hands-on learning: 2 articles. ○ e-Learning: 1 article. ○ Case review: 1 article. ○ Hospital training: 1 article. • **Other areas** ○ Focused examination: 6 articles. ○ Full examination: 1 article. ○ Unclear examination: 2 articles. ○ Diagnostic purpose: 7 articles. ○ Screening purpose: 3 articles. ○ Procedure-related: 3 articles. ○ Lectures: 1 article. ○ Hands-on learning: 2 articles. ○ Case review: 2 articles. ○ Supervised scans: 1 article. ○ Hospital training: 1 article. • Training time for more than one anatomical area ranged from 4 to 320 hours, depending on the level of detail; focused		

Author, Title, Journal	Research Objective	Research Methodology	Sample	Findings	Strengths and Weaknesses	Relevance to Capstone
				POCUS training time ranged from 2.3 to 31 hours of training. • Increased diagnostic accuracy was reported in three with the use of POCUS after adequate training; no association was found between the amount of training and diagnostic accuracy. • False positives stemming from POCUS use were 4-33.3% for cardiac examinations, 0.7-3.2% for obstetrical examinations, 0.5-9.9% for abdominal examinations, 18% for carotid artery examinations, 21.4% for aorta examinations, and 9.7-12.1% for broad health check screenings. 93% of screening examinations for renal cell carcinoma were falsely positive. • Seven studies described false negatives at a rate of 0.02-2.3%. One study showed a false negative rate of 8.7% for cardiac examinations. • Six articles found that patients had positive		

Author, Title, Journal	Research Objective	Research Methodology	Sample	Findings	Strengths and Weaknesses	Relevance to Capstone
				attitudes towards POCUS. • Two articles found that patients living in rural areas had positive attitudes towards POCUS because they did not have to travel. • Three articles found a decrease in health costs with POCUS in general practice compared to secondary care. • Two articles found that 65.6% and 32.1%, respectively, of POCUS scans eliminated the need for further testing. • One study found that 83% of patients would be willing to pay for POCUS.		
Boniface, K. S., Ogle, K., Aalam, A., LeSaux, M., Pyle, M., Mandoorah, M., & Shokoohi, H. (2019). Direct observation assessment of ultrasound competency using a mobile	• Design a smartphone-based standardized direct observation tool and compare a faculty-observed competency assessment at the bedside with a blinded reference standard assessment in	• Quantitative, prospective, cohort study. • Convenience sampling. • Data was collected and collated on SurveyMonkey, a web-based data platform. • Setting was a single emergency department.	• Sample SDOT n = 165, with n = 2 lost to follow-up, leaving total n = 163. • Levels of training among providers performing scans were: ○ Emergency medicine residents (n = 23).	• Image quality: ○ Overall: 87%, k = 0.251, 95% CI [0.02, 0.48]. ○ Fellows: 100%, k = 1. ○ Residents: 87%, k = 0.266, 95% CI [-0.03, 0.56]. ○ Students: 84%, k = 0.254, 95% CI [-0.11, 0.61]. • Image interpretation: ○ Overall: 79%, k = 0.486, 95% CI [0.34, 0.63].	**Strengths** • Unique alternative to traditional methods of POCUS quality assurance. • Useful for resource-limited settings. • Excellent for asynchronous learning. • May have quality assurance	• Suggests that virtual mentorship or teaching may play a role in POCUS education. • Quick, timely use of SDOT can increase faculty-to-learner ratio; helpful, given that POCUS instructors are

Author, Title, Journal	Research Objective	Research Methodology	Sample	Findings	Strengths and Weaknesses	Relevance to Capstone
standardized direct observation tool application with comparison to asynchronous quality assurance evaluation. *Academic Emergency Medicine Education and Training, 3*(2).	the quality assurance (QA) review of ultrasound images.	• SDOTs were checklists of items evaluating the quality of the scan. • QA was traditional quality assurance rounds.	○ Medical students (n = 14). ○ Ultrasonography fellows (n = 4). • Completed SDOTs: ○ Emergency medicine residents (n = 93). ○ Medical students (n = 51). ○ Emergency medicine POCUS fellows (n=19).	○ Fellows: 89%, k = 0.661, 95% CI [0.29, 1]. ○ Residents: 77%, k = 0.412, 95% CI [0.22, 0.61]. ○ Students: 78%, k = 0.513, 95% CI [0.27, 0.76].	available virtually, which would dramatically increase education accessibility. **Weaknesses** • Single centre. • Small sample. • Based on emergency medicine. • Results from SDOT not readily available, thus reducing timely feedback for learners. **Data Analysis** • JBI critical appraisal checklist for cohort studies score: 6/11.	considered a common barrier to POCUS education programs.
Bornemann, P. (2017). Assessment of a novel point-of-care ultrasound (POCUS) curriculum's effect on	• Develop a POCUS curriculum that ensures the requisite knowledge, skills, and attitudes for POCUS use in family practice.	• Quantitative, prospective, observational feasibility study. • Single arm. • Quasi-convenience and quasi-consecutive sampling.	• 17 family medicine residents: ○ 9 post-graduate year (PGY)-1. ○ 6 PGY-2 or 3. • All residents who participated in the curriculum were	• 15 residents completed the pre- and post-rotation knowledge quiz. • 13 residents completed the pre- and post-rotation OSCE. • 12 residents completed the pre- and post-rotation perception survey.	**Strengths** • Authors indicate that this is one of the first studies to address POCUS training for a variety of conditions common to family practice settings.	• Article provides education and competencies required to operate POCUS for select conditions in family practice. • Samples are exclusively

Author, Title, Journal	Research Objective	Research Methodology	Sample	Findings	Strengths and Weaknesses	Relevance to Capstone
competency measures in family medicine graduate medical education. *Journal of Ultrasound Medicine, 36*(6).	• Create a POCUS curriculum that can easily be replicated by other residency programs with or without experienced faculty to teach POCUS.	• Curriculum involved a 4-week rotation consisting of online video lectures, ultrasound simulations, directly and indirectly supervised scanning, and time spent reviewing images in quality assurance sessions. o All online videos are hosted on independent web resources that are widely accessible. • Three pre- and post-rotation assessment tools: o Multiple-choice knowledge quiz. *t*-test used for statistical significance. o Observed structured clinical examination (OSCE) technical skill	automatically enrolled in this study. o All PGY-1 residents were required to participate. o PGY-2 and PGY-3 residents were enrolled in the study if they chose to take the POCUS curriculum as an elective.	• Average multiple-choice knowledge quiz scores increased from 62% to 84%, 95% CI [0.53-0.71; 0.80-0.88]. • Average OSCE scores increased from 41% to 85%, 95% CI [30-52; 79-91]. • Overall perception survey scores (1 being least favourable and 5 being most favourable) improved from 4.4 to 4.6.	• Addresses the primary outcome of curriculum implementation feasibility for other residency programs. • Curriculum is likely generalizable to other programs where limited faculty are trained to operate POCUS. **Weaknesses** • Sample enrollment varies between consecutive (PGY-1) and convenience (PGY-2 and 3), making the sample subject to selection bias, as those who volunteered to enroll in the study were likely to want to study POCUS. **Data Analysis** • JBI critical appraisal checklist for	physicians; can be problematic to generalize to the NPs who are trained in advanced practice nurseing.

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		checklist. *t*-test used for statistical significance. ○ Anonymous survey assessing resident perception of curriculum. Likert scale scores were also used for comparison; no statistical analysis was performed. • All intervention and assessment tools were unblinded with the exception of the perception survey.			quasi-experimental studies score: 4/6 (3 non-applicable).	
Dornhofer, K., Farhat, A., Guan, K., Parker, E., Kong, C., Kim, D., Nguyen, T., Mogi, J., Lahham, S., & Fox, J. C. (2020). Evaluation of a point-of-care ultrasound	• Assess the efficacy of a 4-week POCUS course taught by first-year medical students for physicians, nurses, and midwives in rural Indonesia.	• Quantitative, prospective, observational, cohort study. • Convenience sampling. • Single centre. • Prior to the course, participants were given a pre-test to quantify baseline	• Total n = 55, but n = 2 were unable to attend the final examination, leaving a final total n = 53. ○ Physicians (n = 19). ○ Nurses (n = 13). ○ Midwives (n = 19). ○ 65% had no prior	• No participants passed the pre-test examination. • 79% of physicians, 85% of nurses, and 68% of midwives passed the post-test examination. • Differences in pre- and post-test scores: ○ Physicians: 41% (SD = 13.5). ○ Nurses: 48% (SD = 13.4).	**Strengths** • Study protocol is very clear and comprehensive. • Sample includes ultrasonography-naïve people. **Weaknesses** • Post-test examination had participants performing scans	• Includes nursing practice in its summary. • Shows that learning how to acquire ultrasonographic images is a skill that anyone can learn with appropriate education.

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curriculum taught by medical students for physicians, nurses, and midwives in rural Indonesia. *Journal of Clinical Ultrasound, 48*(3).		ultrasonography concepts. • Course content included lectures, supervised scanning, and quality assurance, totalling 6 hours of lectures and 18 hours of supervised scanning over six sessions. • Lessons included cardiac, biliary, hepatic, pulmonary, renal, vascular, integumentary, and genitourinary systems. • Post-test was completed to compare with pre-test scores; post-test was the exact same as the pre-test.	ultrasonography exposure. ○ 73% had seen ultrasonography used in the past. ○ 7% had previously enrolled in and taken an ultrasonography course. ○ 48% of nurses had no prior exposure, 48% had seen ultrasonography used, and 4% had taken a prior course.	○ Midwives: 38% (SD = 19).	on health volunteers, which confounds the results, as there is no pathology representation. • Training curriculum does not meet WHO guidelines for diagnostic ultrasonography. • No long-term follow-up or data available. **Data Analysis** • JBI critical appraisal checklist for cohort studies score: 5/11.	• Consistent with prior literature demonstrating that a combination of didactic education and observed scanning time is needed to learn POCUS. • Study does not describe clinical integration of POCUS, which is arguably the most difficult step.
Hall, E. A., Matilsky, D., Zang, R., Hase, N., Habibu Ali, A., Henwood, P. C., & Dean, A. J. (2021).	• Analyze the success of a longitudinal point-of-care ultrasound training program for antepartum obstetrical care	• Quantitative, prospective, observational, cohort study. • Convenience sampling. • Multi-centre.	• Total n = 15, but n = 2 were unable to complete training, leaving a final total n = 13. ○ Physicians (n = 2).	• 1338 proctored scans were performed, averaging 109 per participant. • Final written exam scores when compared to pre-test: ○ Physicians: 87.5 +/- 2.5%.	**Strengths** • Study protocol is very clear and comprehensive. • Study meets WHO standards for ultrasonography training.	• Demonstrates that anyone with dedicated training can learn POCUS. • Recommends more frequent OSCE-style assessments to

Author, Title, Journal	Research Objective	Research Methodology	Sample	Findings	Strengths and Weaknesses	Relevance to Capstone
Analysis of an obstetrics point-of-care ultrasound training program for health care practitioners in Zanzibar, Tanzania. *The Ultrasound Journal*, *13*(1).	providers in Zanzibar.	• Conducted in Zanzibar PHC units. • Taught by four emergency physicians and two specialists in obstetrics and gynaecology. • Training program consisted of 30 hours of theoretical teaching and 75 supervised obstetric scans, with a 2-week training course on ultrasonography equipment, physics, and core obstetrical knowledge. This was followed by 6 months of longitudinal supervision and training that averaged 6 to 7 hours of in-person training. • Pre-test assessing prior ultrasonography knowledge, an objective	○ Nurses/ midwives (n = 8). ○ Clinical officers (n = 3). • Clinical officers are professionals who have received 3 years of medical education and have practice patterns similar to physician assistants in the USA.	○ Nurses/midwives: 73.7 +/- 13.5%. ○ Clinical officers: 80.9 +/-5.4%. • Mean OSCE scores increased from 71.2%, 95% CI [62.3%, 80.1%] to 84.7%, 95% CI [78.5%, 90.8%] between 19 and 27 weeks. • 8 of the 13 participants successfully met the requirements of the program, 6 of whom were nurses.	• Makes education recommendations. **Weaknesses** • Study population is based in Tanzania, which has a different education and public health system, making generalizability to the Canadian context limited. • Convenience sampling biases results. **Data Analysis** • JBI critical appraisal checklist for cohort studies score: 7/11.	help determine those who require additional training and those who do not.

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		structured clinical examination (OSCE) at 17 weeks, and a final OSCE and written exam at 27 weeks.				
Homar, V., Gale, Z. K., Lainscak, M., & Svab, I. (2020). Knowledge and skills required to perform point-of-care ultrasonography in family practice – a modified Delphi study among family physicians in Slovenia. *Biomedical Central Family Practice, 21*(56).	• Identify the indications for using POCUS among Slovenian FPs, explore the barriers to POCUS use among them, and provide an expert consensus on knowledge and skills required to effectively implement POCUS in family practice.	• Quantitative, observational, descriptive, two-round Delphi study. • Multi-centre.	• Total n = 13. • All participants had completed at least one ultrasonography course. • Recruitment through snowball sampling. • Inclusion criteria: ○ Being a family physician or family practice specialist or trainee in Slovenia. ○ Use POCUS in family practice.	• First round of questionnaire answered by 13 participants. ○ 34 indications, grouped into five systems: lungs, cardiovascular, abdominal, musculoskeletal, and life-threatening situations. ○ 13 barriers, grouped into three categories: organization, education, and finance. ○ 11 different knowledge and skill types, grouped into three categories: knowledge, skills, and education. • Round two results: ○ Skills in clinical examination, clinical knowledge, knowledge of anatomy, knowledge of using and handling the probes, and education regarding the	**Strengths** • Answers specific questions related to POCUS in primary care. • Quantifies the important knowledge, skills, and education competencies for POCUS use. **Weaknesses** • Consensus-based survey puts findings at risk of bias. • Methodology makes finding results akin to expert opinion, the lowest level on hierarchy of evidence. • Small sample size makes generalization difficult.	• Strong consensus regarding the knowledge, skills, and education required to operate POCUS in family practice. • Family practice-specific data. • Consistent with other research studies in this field.

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				possibility of remote consultation with a radiologist or experienced colleague had unanimous support, followed by tutorship and handling of portable ultrasonography devices.	• Based in Slovenia; may not be relevant to Canadian public health system. **Data Analysis** • JBI critical appraisal checklist for case control studies score: 6/8 (2 non-applicable). • JBI critical appraisal checklist for text and opinion papers score: 5/6.	
Kimambo, D., Kennedy, S., Kifai, E., Kailembo, N., Eichberg, C., Markosky, S., Shah, I., Powers, E., Zwerner, P., Dorman, S. E., Janabi, M., & Bayer, R. (2021). Feasibility of point-of-care cardiac	• Determine feasibility of cardiac POCUS performed by clinicians at health centres in Tanzania.	• Retrospective, observational, cohort study and a narrative summary of a novel POCUS use for focused cardiac assessments. • 5-day course containing didactic and experiential methods according to pre-defined protocols.	• Total participants (n = 8): ○ Physicians (n = 1). ○ Assistant medical officers (n = 1). ○ Clinical officers (n = 6). • 1 participant had prior antenatal ultrasonography experience, and 1 other participant had prior antenatal and abdominal	• Increased post-training test results when compared to pre-test for basic cardiac anatomy and physiology and clinical integration of ultrasound images and video clips. • Mean 51 scans per participant. • Best correlator with obtaining and interpreting images was high number of ultrasonography scans; all other predictors not statistically significant.	**Strengths** • Describes POCUS operator characteristics that predict favourable image generation and interpretation. • Evaluates non-physician POCUS operators. **Weaknesses** • Selection bias for patients and participants hampers	• Suggests that POCUS education and training programs may benefit from being shorter in duration (5 days). • Emphasis on performing and interpreting scans seems to be more beneficial for learning than lectures, as

Author, Title, Journal	**Research Objective**	**Research Methodology**	**Sample**	**Findings**	**Strengths and Weaknesses**	**Relevance to Capstone**
ultrasound performed by clinicians at health centers in Tanzania. *Biomedical Central Cardiovascular Disorders*, *21*(1).		• Pre- and post-test training and post-training image acquisition and interpretation were assessed. Models were recruited from hospital inpatient wards and healthy volunteers. • A blinded cardiologist reviewed all images, graded them, and provided their interpretation; this was considered the gold standard.	ultrasonography experience.	• Very poor inter-rater agreement for interpretation of images: ○ Pericardial effusion: k = -0.03, 95% CI [-0.04, 0.02] ○ Left ventricular dysfunction: k = 0.17, 95% CI [0.07, 0.28] ○ Aortic regurgitation: k = 0.28, 95% CI [0.14, 0.41] ○ Mitral valve regurgitation: k = 0.29, 95% CI [0.14, 0.44] ○ Tricuspid valve regurgitation: k = 0.42, 95% CI [0.25, 0.59] ○ Mitral valve stenosis: k = 0	methodological rigour. • Low prevalence of the key pathologies, which may confound test results. • Very small sample sizes make findings underwhelming, as they risk being over-exaggerated or under-represented. • Many findings are not statistically significant above the predefined 95% CI. **Data Analysis** • JBI critical appraisal checklist for cohort studies score: 7/11.	evidenced by the 75% and 25% split, respectively.
Lindgaard, K., & Riisgaard, L. (2017). Validation of ultrasound examinations performed by	• Evaluate the quality of ultrasound examinations performed by general practitioners and explore the inter-rater	• Quantitative, prospective, observational, cohort study. • Convenience sampling. • Multi-centre. • Conducted in Denmark.	• Final total scans included in the study (n = 104). ○ 10 patients were lost to follow-up. • POCUS scans included in the study:	• All scans: k = 0.93, 95% CI [0.87, 0.97]. • Gallstones: k = 0.84, 95% CI [0.69, 0.97]. • Ascites: k = 100, 95% CI [1, 1]. • Abdominal aorta > 5 cm in diameter: k = 1, 95% CI [1, 1].	**Strengths** • One of the few studies that assesses inter-rater agreement of POCUS in the primary setting rather than a	• Underscores how quality, established POCUS education can lead to high levels of agreement

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general practitioners. *Scandinavian Journal of Primary Health Care*, *35*(3).	agreement between general practitioners and radiologists/ gynaecologists within a limited range of ultrasound examinations.	• Ultrasonography examinations limited to people with abdominal pain with or without pregnancy. • Primary outcome is inter-rater agreement between general practitioners and radiologists or gynaecologists. • Five general practitioners were recruited from five different clinics, one of whom was a family medicine resident. None had prior ultrasonography experience. • GPs were enrolled in an established ultrasonography course, which consisted of an e-learning section and two educational days with hands-on ultrasound examinations with	○ Gallstones (62 scans). ○ Ascites (34 scans). ○ Abdominal aorta > 5 cm in diameter (29 scans). ○ Intrauterine pregnancy (33 scans). ○ Gestational age (30 scans).	• Intrauterine pregnancy: k = 100, 95% CI [1, 1]. • Gestational age: k = 93. No confidence interval available.	predefined gold-standard test. • Multi-centre locations allow for heterogeneity among POCUS operators, thus strengthening results. **Weaknesses** • Convenience sampling predisposes findings to bias. • 7% of patients lost to follow-up. • Cannot draw conclusions from inter-rater agreement findings for gestational age, given that there were no binary standards included in the study. • Unable to detect improvement in POCUS operation over the duration of the study. **Data Analysis** • JBI critical appraisal	between GPs and specialists. • Suggests that a combination of didactic and hands-on instructional methods are of benefit to learning POCUS, in addition to at least 30 scans for each organ system.

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		direct feedback from instructors. GPs were required to perform 25 scans. Results were then sent to a radiologist or gynaecologist who was blinded to the operator. Inter-rater agreement was then calculated.			checklist for cohort studies score: 10/11.	
Safavi, A. H., Shi, Q., Ding, M., Kotait, M., Profetto, J., Mohialdin, V., & Shali, A. (2018). Structured, small-group hands-on teaching sessions improve pre-clerk knowledge and confidence in point-of-care ultrasound use and interpretation. *Cureus*, *10*(10).	• Determine if a structured, small-group POCUS teaching session with predefined learning objectives, an introductory presentation, and a mandatory hands-on scanning component would increase medical students' knowledge of and confidence in POCUS theory, use, and interpretation.	• Quantitative, prospective, observational, cohort study. • Convenience sampling. • Outcome was to assess if a POCUS course with a pre-defined structure would increase knowledge of and confidence in POCUS theory, use, and interpretation among medical students. • Participants were assigned to small groups where they were taught	• Total participants (n = 27). • Participants were medical students at McMaster University. • Recruited through a class Facebook discussion group. • Participation was voluntary. • Medical students were in the pre-clinical years.	• Post-test scores showed a 59.3% ($p = <0.05$) increase in knowledge, a 51.9% increase in confidence ($p = <0.05$), and a 24.8% increase in confidence regarding POCUS interpretation ($p = <0.05$), with 92.6% of participants agreeing or strongly agreeing that they liked the introductory presentation, 100% of participants agreeing or strongly agreeing that they liked the session content, 100% of participants agreeing or strongly agreeing that they liked the session's structure, and 70.4% of participants agreeing or strongly agreeing that	**Strengths** • Is a Canadian study that best represents the context of medical students. • Shows that small educational sessions may be beneficial in improving confidence to operate POCUS. **Weaknesses** • Weak sample recruitment puts study at risk for bias. • Only 18% of participants responded to the	• Shows that short POCUS education sessions can increase confidence surrounding its use. • May be helpful to inform ongoing professional development or competency maintenance training sessions. • Underscores that a variety of teaching methods is best to increase confidence in

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		by an ultrasonography expert. • The teaching session lasted 90 minutes, of which 15 minutes were allocated to didactic teaching and the remaining time to hands-on practice. • Participants from each small group would volunteer as models to practice scanning. • A pre- and post-test survey was used to measure the primary outcome.		they were satisfied with the level of theoretical understanding of POCUS and how it could be used in practice.	recruitment for the program. • Does not address the specifics of the competencies required to operate POCUS. **Data Analysis** • JBI critical appraisal checklist for cohort studies score: 6/10 (1 non-applicable).	POCUS operation, and shows the importance of a mentor to help the learner operate the device.
Situ-LaCasse, E., Acuña, J., Huynh, D., Amini, R., Irving, S., Samsel, K., Patanwala, A. E., Biffar, D. E., & Adhikari, S. (2021). Can ultrasound novices develop image	• Determine if first-year medical students without ultrasonography experience can learn ultrasound techniques and develop psychomotor skills to acquire ultrasound images after only reviewing online modules.	• Quantitative, prospective, observational, cohort study. • Unclear recruitment; was apparently voluntary. • Single centre. • Primary outcome was image acquisition performance based on a scoring system	• First-year medical students in Arizona, USA (n = 44). • All participants did not have experience with ultrasonography.	• Overall scores ranged from 46.5-97.7% for image acquisition as performed by participants. • Positive association was found between completion of online modules and hands-on skills evaluation. • Participants who did not complete the online modules consistently scored lower on the hands-on skill sessions	**Strengths** • First study that researched online-only learning to determine POCUS competency for select uses. • Answers a very important question in the era of e-learning and COVID-19, where physical distancing	• Examines the role of e-learning in the development of POCUS knowledge and skills. • Participants did not have ultrasonography experience, which may reflect NPs.

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acquisition skills after reviewing online ultrasound modules? *Biomedical Central Medical Education*, *21*(1), 175.		used by ultrasonography faculty. • Study participants were assigned four anatomy and physiology ultrasound online modules, then tested on their hands-on skills a week later. They were tested through quizzes and probe technique. Ultrasonography faculty would score the participant based on their ability to acquire an ultrasound image. • Online content was provided by SonoSim Ultrasound Training Solution, a company that specializes in online ultrasonography education.		compared to participants who completed all online modules.	measures are the norm. **Weaknesses** • Small sample and single institution limit generalizability. • Voluntary recruitment pre-disposes results to selection bias, as those who are interested are more likely to learn POCUS. • Only used the SonoSim e-learning modules. **Data Analysis** • JBI critical appraisal checklist for cohort studies score: 7/11.	
Snelling, P. J., Jones, P., Keijzers, G., Bade, D., Herd,	• Describe the diagnostic accuracy of NP-operated	• Quantitative, prospective, observational,	• NPs (n = 6) who work in an emergency	• NP-operated POCUS had a sensitivity of 94.6%, 95% CI [89.2%,	**Strengths** • NPs are primary population studied.	• Shows that NPs can learn POCUS with appropriate

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D. W., & Ware, R. S. (2021). Nurse practitioner administered point-of-care ultrasound compared with X-ray for children with clinically non-angulated distal forearm fractures in the ED: A diagnostic study. *Emergency Medicine Journal*, *38*(2), 139–145.	POCUS compared to radiography.	cohort, diagnostic study. • Children presenting to an emergency department with a non-angulated distal forearm injury were triaged by an emergency nurse. • Children included in the study were first examined with POCUS to determine the presence of fracture, and the results were subsequently compared with radiography. • The primary outcome was accuracy of NP-operated POCUS for non-angulated distal forearm fractures compared to radiography. • NPs learned POCUS through a two-hour didactic training course followed by three	department in Australia. • Total patients enrolled in study (n = 204). • Convenience sampling.	97.3%] for buckle fractures. • NP-operated POCUS had a specificity of 85.3%, 95% CI [75.6%, 91.6%] for buckle fractures. • Overall sensitivity and specificity of POCUS for non-buckle fractures were 81% and 95.9%, 95% CI [69.1%, 89.1%; 91.3%, 98.1%], respectively. • 50% of the NPs conducted 86.8% of the POCUS scans. • NP-operated POCUS was associated with similar pain scores by the child and decreased reports of pain by the parent.	• Answers a clinically useful question, particularly in primary care, where access to radiography is limited. • Excellent sensitivity for detection of non-angulated distal forearm fractures. **Weaknesses** • Small sample size of NPs and patients. • Selection bias is present, given that an emergency nurse had triaged patients. • Weak specificity for non-angulated distal forearm fractures suggests many false positives related to NP-operated POCUS. **Data Analysis** • JBI critical appraisal checklist for diagnostic test	training and education. • Short training session suggests that NPs require a combination of didactic and hands-on training. • Interestingly, only three proctored scans were conducted before the study; questions remain about whether more proctored scans could lead to even better sensitivity and greater specificity for the detection of non-angulated distal forearm fractures.

Author, Title, Journal	Research Objective	Research Methodology	Sample	Findings	Strengths and Weaknesses	Relevance to Capstone
		proctored scans on actual patients.			accuracy studies score: 10/10.	
Tuvali, O., Sadeh, R., Kobal, S., Yarza, S., Golan, Y., & Fuchs, L. (2020). The long-term effect of short point of care ultrasound course on physicians' daily practice. *PLoS ONE*, *15*(11).	• Measure the change in daily POCUS use by practicing physicians after taking short POCUS courses.	• Quantitative, prospective, case-control study. • Participants recruited via database. • 13-statement questionnaire was sent to physicians who attended a 5-day POCUS course, which consisted of 13 hours of hands-on practice and 18 hours of lectures at a university-affiliated hospital in Israel. • The survey used Likert scale-like methods.	• Total respondents (n = 116), with a response rate of 54.7%. ○ Anaesthesia and critical care (n = 27). ○ Cardiology and cardiac surgery (n = 3). ○ Emergency medicine (n = 10). ○ Internal medicine (n = 65). ○ Surgery (n = 5). ○ Pediatrics (n = 4).	• 22.4% of respondents rated their POCUS usage as "no use at all" and "minimal use only," down from 84.9% before the course. • 77.6% of respondents rated their POCUS usage as "moderate use" or "multiple use," up from 16% before the course. • 75.8%, 95% CI [68%, 83.59%] of respondents agree or strongly agree that POCUS can improve patient care. • 84.4%, 95% CI [77.8%, 91%] of respondents agree or strongly agree that POCUS can increase quality of diagnosis. • 76.7%, 95% CI [69%, 84.3%] of respondents agree or strongly agree that POCUS can shorten diagnosis time. • 98.4%, 95% CI [86.4%, 100%] of respondents agree or strongly agree that POCUS should be incorporated into medical training.	**Strengths** • Shows that some degree of POCUS education and training dramatically increases use. **Weaknesses** • Selection bias makes generalization of study findings limited. • Data is largely subjective. • Findings showing positive attitudes toward POCUS among survey respondents do not necessarily correlate with competence to operate POCUS. **Data Analysis** JBI critical appraisal checklist for case control studies score: 3/6 (4 non-applicable).	• Shows that formal POCUS education can increase rates of adopting POCUS in clinical practice, which is important, given that an abundance of data is supporting routine POCUS use in primary care settings.

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Wong, F., Franco, Z., Phelan, M. B., Lam, C., & David, A. (2013). Development of a pilot family medicine hand-carried ultrasound course. *Wisconsin Medical Journal*, *112*(6).	• Identify aspects of the various components of a hand-carried ultrasound training session, the need for future training, and the impact on participants' self-perceived comfort and proficiency in operating POCUS.	• Quantitative, prospective, analytical, cohort study. • A training session consisting of lectures, case review, and hands-on practice with four standardized patients was taught by an emergency physician with expertise in POCUS. Participants completed a pre- and post-training survey to quantify their self-perceived confidence and proficiency in operating POCUS. • Participants were also given open-ended questions to determine what future POCUS training programs should entail.	• Total participants (n = 8). • Participants were family physicians. • All participants were faculty members at the Medical College of Wisconsin's Department of Family and Community Medicine program. • All participants were volunteers.	• All post-test training levels of agreement were significantly improved after the POCUS course. • Participants indicated that hands-on training with standardized patients is the most effective form of education, followed by review and discussion of case studies.	**Strengths** • Describes what components of POCUS education and training should be included. **Weaknesses** • Poor methodology due to small sample size, sampling method, and no participant characteristics provided. • Results subject to bias, given that no non-faculty participants were included in the study. **Data Analysis** • JBI critical appraisal checklist for cohort studies score: 5/10 (1 non-applicable).	• Describes components of one POCUS education program in detail. • Provides education specifics related to primary care practice.
Yamada, T., Minami, T., Soni, N. J.,	• Examine the effect of the same POCUS	• Quantitative, prospective, cohort study.	• Total n = 60. ○ 9 lost to follow-up.	• Image interpretation results:	**Strengths** • Addresses an unknown area of	• While results are not statistically significant, the

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Hiraoka, E., Takahashi, H., Okubo, T., & Sato, J. (2018). Skills acquisition for novice learners after a point-of-care ultrasound course: Does clinical rank matter? *Biomedical Central Medical Education, 18*(202).	training program on skills acquisition and confidence of trainees who are novice POCUS users compared to attending physicians who are novice POCUS users.	• Convenience sampling. • Comparison between two groups.	○ n = 51 in final study. ○ n = 29, trainees. ○ n = 22, attending physicians. • Enrollment methodology is unclear.	○ Mean pre- and post-course tests for all participants were 66% (SD 12.9) and 82.8% (SD 9), respectively. ○ Pre-course tests were 65.5% (SD 13) and 66.7% (SD 13); post-course tests were 83.9% (SD 9) and 81.5% (SD 9) for trainees and attending physicians, respectively. • Confidence score results: ○ Mean pre- and post-course evaluation scores were 2.37 (SD 0.9) vs. 3.32 (SD 0.71) for general ultrasound skills; 2.56 (SD 0.84) vs. 3.6 (SD 0.71) for focused cardiac ultrasound; 1.94 (SD 0.9) vs. 3.55 (SD 0.7) for vascular diagnostics; 1.77 (SD 0.76) vs. 3.3 (SD 0.7) for lung/diaphragm ultrasound; and 2.95 (SD 0.97) vs. 3.81 (SD 0.75) for abdominal ultrasound, respectively. ○ Results were not statistically significant.	POCUS education as the majority of POCUS training programs categorize education based on clinical rank rather than baseline POCUS experience. • There is representation of both hospital and non-hospital providers. • Study suggests that individuals who are motivated to learn POCUS can do so with appropriate theory and hands-on training in a relatively short training session. **Weaknesses** • Convenience sampling and unclear enrollment strategy hinders external validity. • Samples voluntarily enrolled in the study after seeing an advertisement	curriculum demonstrates that an appropriate combination of theory and hands-on training, along with mentorship, are likely the core components that inform quality POCUS education. • Heterogeneity of clinical practice among samples suggests that learning POCUS is not exclusive to a medical practice; rather, it is a skill and technique that can be learned by anyone motivated to acquire appropriate training. • Study addresses how POCUS education can be provided but lacks data informing what core competencies are

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				• Satisfaction score results: ○ On a Likert scale out of 5: ○ 4.5 for overall satisfaction. ○ 4.6 for satisfaction with faculty member's teaching skills. ○ 3.7 for satisfaction with time management.	for it at a conference. This suggests that the samples were already interested in POCUS. • Unclear what type of internal medicine subspecialty was included. • Results were not statistically significant. • NPs are not represented. • 9 participants lost; no explanation provided. • Participants were overwhelmingly male (88%). • No exclusion criteria available. **Data Analysis** • JBI critical appraisal checklist for cohort studies score: 7/11.	required to safely operate POCUS.

Text, Narrative, and Expert Opinion

Author, Title, Journal, Year	Objective	Arguments	Strengths and Weaknesses	Relevance to Capstone
Barron, K. R., Wagner, M. S., Hunt, P. S., Rao, V. V., Bell, F. E., Abdel-Ghani, S., Schrift, D., Norton, D., Bornemann, P. H., Haddad, R., & Hoppman, R. A. (2019). A primary care ultrasound fellowship: Training for clinical practice and future educators. *Journal of Ultrasound in Medicine, 38*(4).	Summarize the expansion of POCUS training across primary care specialties in the USA and describe the South Carolina School of Medicine primary care ultrasound fellowship for medical students, residents of internal medicine, pediatrics, and family medicine. Retrospective, observational, and narrative study.	• Five physicians have completed the fellowship. ○ All are now engaged in some degree of ultrasound teaching since completing the program. ○ Three of the physicians have academic appointments. ○ One physician has a faculty appointment with ultrasound teaching responsibilities. • Provides objective curriculum descriptions: ○ 1-2 months of specialty-specific ultrasound rotations. ○ Minimum of 500 POCUS studies under direct or indirect supervision. ○ Didactic teaching. ○ Scanning rounds with faculty. ○ Quality assurance review with faculty. • Training in the following specialties to develop competency: ○ Cardiology ○ Radiology ○ Emergency medicine ○ Critical care medicine ○ Obstetrics ○ Pediatrics ○ Family medicine ○ Sports medicine	• Describes a training program specific to family medicine. • While in its relative infancy, describes the success of five alumni. **Weaknesses** • No long-term data showing that the program is the best model for POCUS training. • This POCUS training program is arguably very resource-intensive. **Data Analysis** • JBI critical appraisal checklist for text and opinion articles score: 6/6.	• Based on family medicine and thus primary care. • Provides objective curriculum descriptions: ○ 1-2 months of specialty-specific ultrasound rotations. ○ Minimum of 500 POCUS studies under direct or indirect supervision. ○ Didactic teaching. ○ Scanning rounds with faculty. • Quality assurance review with faculty.

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		○ Rheumatology ○ Registered sonographers		
Chamsi-Pasha, M. A., Sengupta, P. P., & Zoghbi, W. A. (2017). Handheld echocardiography: Current state and future perspectives. *Circulation, 136*(22).	Intended for all users of POCUS echocardiography.	• Summarizes the literature surrounding the use of handheld echocardiography in conducting cardiac assessments, as well as its training requirements, challenges, opportunities, and future perspectives.	**Strengths** • Provides a general overview of focused echocardiography with POCUS devices. • Describes current state of echocardiography training with POCUS for all providers. **Weaknesses** • While the authors mention the need for high-quality training, they make no training recommendations. **Data Analysis** JBI critical appraisal checklist for text and opinion papers score: 5/6.	• Includes nursing practice among its summary. • Describes the role of virtual POCUS echocardiography and how POCUS can reduce barriers to health care access. • Summarizes that the best-known curriculum for acquiring competency in POCUS echocardiography includes 12 one-hour lectures along with a weekly one-hour bedside teaching session and 10-30 scans supervised by sonographers.
Micks, T., Smith, A., Parsons, M., Locke, T., & Rogers, P. (2016). Point-of-care ultrasonography training for rural family medicine residents – its time has arrived. *Canadian Journal of Rural Medicine, 21*(1), 28-29.	Narrative, summary article of one family medicine resident's experience. Target population is family medicine physicians and residents in rural settings.	• As of October 2014, there is only one Canadian rural family medicine POCUS training program, and it is offered at Memorial University. This program consists of online lectures and basic ultrasonography concepts and skills. There is a 1.5-day competency development section where specific POCUS skills are taught. • The program bases competency on the	**Strengths** • Only Canadian study looking at competency training for rural family physicians. • Provides a single anecdote of the number of practice scans required to be competent to operate POCUS. **Weaknesses** • Narrative summary format makes conclusions difficult to generalize, although	• Specific to the Canadian context, particularly rural practitioners. • Highlights the fact that a combination of self-paced e-learning modules and dedicated supervision can lead to competency in POCUS operation.

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		Canadian Emergency Ultrasound Society Independent Practitioner guidelines—that is, 50 supervised scans for each use, followed by a written, visual, and practical examination. • Most participants complete 10-15 supervised scans before moving on to their competency training section.	face value suggests feasibility. **Data Analysis** • JBI critical appraisal checklist for text and opinion papers score: 4/6.	

Practice Guidelines

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American Academy of Family Physicians. (2016, December). *Recommended curriculum guidelines for family medicine residents: Point-of-care ultrasound.*	• Defines a recommended training strategy for family medicine residents.	• Family physicians and family medicine residents.	• Lists six competencies that family medicine residents will possess after POCUS training in residency: ○ Patient care. ○ Medical knowledge. ○ Practice-based learning and improvement. ○ Interpersonal and communication skills. ○ Professionalism. ○ Systems-based practice. • Lists the attitudes and behaviours that family medicine residents	**Strengths** • Addresses the specifics of POCUS education, quality assurance, continuing competence, and resources for family medicine residencies. • Quantifies specific number of POCUS scans required to be deemed competent. • Comprehensive. **Weaknesses** Guideline is for physicians and family	• Highly relevant given its detail on how to structure POCUS education. • May not apply to licensed NPs who are practicing, as the curriculum guideline seems to be intended for the long term. • Useful for informing prospective POCUS programs during NP education.

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			should possess after POCUS training: ○ Understand limitations of POCUS. ○ Understand how POCUS assists with diagnostic reasoning. • Have knowledge of physics, orientation, terminology, image optimization, applications, safety, modes, and documentation related to POCUS. • Have knowledge of the core applications of POCUS in family medicine: ○ Obstetrics and gynaecology. ○ Cardiac. ○ Trauma. ○ Aorta. ○ Biliary. ○ Urinary tract. ○ Deep vein thrombosis. ○ Soft tissue/musculoskeletal. ○ Thoracic/pulmonary. ○ Ocular. ○ Procedural guidance. ○ Clinical protocols. ○ Prospective curriculum and training programs should include: Faculty champion.	medicine residency programs. **Data Analysis** • AGREE II reporting checklist score: 32/87.	

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			○ Customized curriculum to meet specific needs of target audience. ○ Didactic education. ○ Hands-on education including simulators and healthy volunteers. ○ Educational ultrasonography on patients once they have consented that the scan is for educational purposes only. ○ Knowledge and skill assessment through structured, formal, and informal modalities. Both formative and summative feedback is recommended. ○ Quality improvement should accompany ongoing education. ○ Competency assessment requires a series of objective assessments through examinations or OSCE-style tests. Also recommended: minimum of 150-300 total scans for general POCUS competency, 25-50 supervised scans for specific		

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			diagnostic exams, and 5-10 supervised scans for procedural guidance. An individual assessment of each resident should also be conducted on a case-by-case basis.		
American College of Emergency Physicians. (2016, June). *Ultrasound guidelines: Emergency, point-of-care, and clinical ultrasound*	• Provide leadership and guidance for POCUS education in emergency medicine and emergency medicine training programs.	• Emergency physicians, advanced practice providers, nurses, and paramedics.	• Recommends that clinicians must be aware of indications and contraindications for performing POCUS. • Recommends that clinicians must know how to acquire adequate POCUS images and be familiar with ultrasonography physics and how to operate the device. • Recommends that clinicians must understand how to integrate POCUS findings into patient care. • Clinicians must be familiar with how to properly document POCUS findings, determine quality assurance, and calculate reimbursement. • Recommends a wide range of educational modalities to facilitate	**Strengths** • Addresses the specifics of POCUS education, quality assurance, continuing competence, and required resources. • Quantifies specific number of POCUS scans required to be deemed competent. • Includes NPs in its scope. • Cited literature is relevant to the guideline. **Weaknesses** • Guideline is emergency medicine-centric. Parts of the guideline are not applicable to NPs in BC, such as billing and remuneration. **Data Analysis**	• De facto resource providing guidelines for POCUS education for all professionals, given that emergency medicine has been a leader in POCUS.

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			POCUS learning, including podcasts, lectures, case review, classrooms, flipped classroom models, hands-on practice, and mentorship. • Educational benchmarks should include teaching sessions and image review, standardized knowledge assessments or OSCE-like exams, and simulation assessments. • Recommends 25-50 quality-reviewed scans for a particular application, 150-300 total scans for any exam being used, at least 10 additional scans for special uses such as endovaginal scans, and five scans for psychomotor skills. • Ongoing competency maintenance should include at least 5-10% of scans which must undergo peer review. ○ Recommends two training pathways: Residency-based pathway for post-graduate training.	• AGREE II reporting checklist score: 55/87.	

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			○ Practice-based pathway for those who are not in postgraduate residency training; this should include a comprehensive course, a series of short courses, or a preceptorship. All training sessions must include some degree of physics, device manipulation, didactics, and hands-on instruction that pairs learners with trainers who are experienced in image acquisition, interpretation, and integration of POCUS. This pathway applies to NPs. • Credentialing should be standardized. • Supervision of ultrasonography training, documentation, quality improvement process, and risk management must have a standardized process and quality assurance. • Recommends that the core applications of POCUS be: ○ Trauma		

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			○ Intrauterine pregnancy ○ Abdominal aortic aneurysm ○ Cardiac and hemodynamic assessment ○ Biliary ○ Urinary tract ○ Deep vein thrombosis ○ Soft tissue and musculoskeletal ○ Thoracic/airway ○ Ocular ○ Bowel • Procedural guidance		
Lewis, D., Rang, L., Kim, D., Robichaud, L., Kwan, C., Pham, C., Shefrin, A., Ritcey, B., Atkinson, P., Woo, M., Jelic, T., Dallaire, G., Henneberry, R., Turner, J., Andani, R., Demsey, R., & Olszynski, P. (2019). Recommendations for the use of point-of-care ultrasound (POCUS) by emergency physicians in Canada. *Canadian Journal of Emergency Medicine, 21*(6), 721–726.	Provide emergency physicians in Canada with a framework and recommendations for advancing personal POCUS development, POCUS program development, and/or maintenance.	Canadian emergency physicians and other health care providers.	• Makes recommendations for clinical scope of practice, training and competency, program management, scope for pediatric emergencies, and research. • Core clinical applications include: ○ FAST. ○ Identification of AAA. ○ Identification of intrauterine pregnancy in the first trimester. ○ Thoracic ultrasound. ○ Focused cardiac ultrasound. ○ Ultrasound-guided vascular access. • Scope of practice: ○ Resuscitative. ○ Diagnostic.	**Strengths** • Canadian. • Mentions health care providers other than physicians. • Provides guidelines specific to competency and training for Canadian physicians in training and practicing physicians. • Makes recommendations for non-clinical uses of POCUS. **Weaknesses** • Guideline is emergency medicine-centric.	• Highly relevant to capstone given Canadian context and recommendations for training and education. • Generalizability to NPs is difficult, given that scope of guideline is emergency medicine-centric. • POCUS use, maintenance, and ongoing competency seem to share similarities with primary care; however, this is not directly stated in guideline.

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			○ Procedural guidance. ○ Therapeutic and monitoring. • Training and competency: ○ Education should include direct supervision within and outside of a clinical context, reviewing saved images, simulations, online learning modules, didactic lectures, and ultrasound courses. ○ POCUS courses must have resources available to support a rich learning experience. ○ External competency certification is optional for physicians who have completed postgraduate training. ○ Local guidelines must have accepted, clearly defined POCUS credentials. ○ Physicians who are currently practicing and do not have previous POCUS education should develop basic skills via volunteers or standardized patients in courses, a	**Data Analysis** AGREE II reporting checklist score: 48/87.	• Highlights the need for multiple methods of POCUS education, including supervised and unsupervised scanning, lectures, and summative evaluations.

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			supervised training phase, and approximately 10-50 scans for most clinical applications. ○ Physicians who are currently practicing and do not have previous POCUS education must have a clearly defined introduction to POCUS, supervised training that includes scanning in both clinical and non-clinical settings, and a summative assessment of knowledge and image assessment for the purpose of credentialing and privileging. ○ Health care providers other than physicians must undertake similar education, training, and evaluation before being credentialed to use POCUS. • Program management: ○ Must have a designated POCUS leader for each emergency POCUS program. ○ Documentation of all POCUS scans must be		

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			added to a patient's record and be readily available for other providers to read. ○ Image archiving is strongly recommended. • Emergency pediatric scope: ○ Core clinical applications include FAST, cardiac ultrasonography, ultrasound-guided vascular access, thoracic ultrasonography, identification of first-trimester intrauterine pregnancy, cellulitis, abscess, and foreign bodies. ○ Scope of practice includes resuscitation, pulmonary, neck, ocular, renal/bladder, skull, abdomen, testes, hip, and fractures. ○ Training and education mirror the adult POCUS requirements. • Research: ○ Efforts should be made to prove causation, as there is a gap in proving true		

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			outcome benefit with POCUS.		
The Society of Point-of-Care Ultrasound. (2018). Guidelines for point-of-care ultrasound utilization in clinical practice. *The Society of Point-of-Care Ultrasound.*	Establish clear and consistent guidelines for the definition, training requirements, and suggested pathways of training, certification, privileging, credentialing, models of practice, skill sustainment, leadership, advocacy, quality assurance, documentation requirements, billing, and reimbursement for POCUS.	All providers who perform POCUS. NPs are not specifically named rather they are included as a provider under the term advanced practice providers (APPs), and this is a term used to describe physician assistants and advanced practice nurses in the United States, where SPOCUS is based (Kreeftenberg et al., 2019).	**POCUS Definition and Scope** • Defines and describes the differences between traditional ultrasound and POCUS examinations. • POCUS is narrow in scope and meant to answer a specific clinical question. **Competency-Based Training** • Recommends four key areas for safe, appropriate POCUS implementation: knowledge related to indications for the exam, image acquisition, image interpretation, and integration of the findings into patient care. • Acquiring competency in the four key areas requires didactic education through online programs, lectures, clinical preceptorships and rotations, conferences, graduate and fellowship training programs, medical	**Strengths** • Very comprehensive practice guideline that includes all providers who may use POCUS. • The guideline proposes quantifiable objectives where possible. • Clearly states that individual organizations and societies should set the competencies for POCUS integration into clinical practice. • Provides practice guidelines beyond clinical application of POCUS. • Addresses the continued development of POCUS education and advancement. **Weaknesses** • Training competencies are largely based on POCUS within medical education. • SPOCUS does not have a physician	• Highly relevant to the proposed capstone project. • Provides clear guidelines for training and competency requirements to operate POCUS. • Provides guidelines for certification, privileging, credentialing, and skill sustainment. • Guideline goes beyond competencies required for curriculum development and includes suggested leadership and advocacy pathways. • There is no comparable Canadian guideline, which underscores the importance of this resource.

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			school, or medical education programs. • Acquiring competency in the four key areas also requires hands-on training through one-on-one scanning, conferences, remote video conferencing, or ultrasound simulation technology. • Acquiring competency in the four key areas also requires objective demonstration through written exams, supervision, simulation cases, or standardized objective exams, such as the objective structured clinical examination. • Suggested goal: 150-300 proctored ultrasound scans for each POCUS skill. • Competency training should be divided into two phases: ○ Phase one should introduce POCUS training into undergraduate or graduate education and professional development courses for practicing clinicians.	representative on their board of directors; lack of physician representation makes the spirit of multidisciplinary support less robust. • References are heavily based on EM literature, followed by critical care medicine literature. There are limited references to internal medicine literature, which arguably has the second-largest body of POCUS evidence. **Data Analysis** • AGREE II reporting checklist score: 39/87.	

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			○ Phase two should consist of proctored scanning. **Certification** • Training and proficiency standards should be developed by respective professional and specialty organizations and complement existing standards previously set by other professional organizations/colleges. • In the absence of specialty- or practice-specific competency standards, clinicians should use validated standards previously set by other professional societies or organizations. • External organization certifications to determine proficiency of training are not recommended. **Privileging and Credentialing** • Privileging and credentialing for POCUS should be held to the same standard as licensing.		

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			• There is no specific number of scans that guarantee competence; however, 25 exams for each POCUS skill and 150-300 general scans, of which 5% are with pathology, are recommended. Procedures guided with POCUS require a minimum of 5-10 proctored scans to ensure competence. • APPs are encouraged to follow the above guidelines should no specific guidelines exist for APPs. **Models of Practice** • Makes suggestions to take legal, procedural, and patient factors as well as personal and local setting variables into account when deciding to use POCUS. **Skill Sustainment** • A two-year credentialing renewal cycle is recommended. • No minimum number of scans is required for skill sustainment.		

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			• At least 5% of professional development must be dedicated to POCUS. **Leadership/Advocacy** • Must have a structure in place to advance use of POCUS through policy and clinical practice. • Leadership should be multidisciplinary. **Quality Assurance and Performance Improvement** • A quality improvement and assurance program must complement the clinical use of POCUS. **Value and Safety** • Use the lowest possible energy intensity and the shortest possible duration when using POCUS. • Address incidental findings similarly to how one would address comparable findings from a traditional ultrasound. **Documentation Requirements**		

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			• POCUS documentation should be held to the same standards as other diagnostic imaging modalities. • Acquired images must be stored and retrievable. **Billing and Reimbursement** • Must have a reimbursement structure in place. Does not apply to the Canadian context.		