ORIGINAL ARTICLE

Identification of Hypertension Management-related Errors in a Personal Digital Assistant-based Clinical Log for Nurses in Advanced Practice Nurse Training

Nam-Ju Lee[1], *DNSc, RN*, *Eunhee Cho*[2]*, *PhD, MPH, CRNP, RN*, *Suzanne Bakken*[3], *DNSc, FAAN, RN*

[1]Full-time Instructor and Researcher, Research Institute of Nursing Science, Seoul National University College of Nursing, Seoul, Korea
[2]Assistant Professor and Researcher, Nursing Policy Research Institute Yonsei University College of Nursing, Seoul, Korea
[3]Alumni Professor of Nursing and Professor of Biomedical Informatics, Columbia University School of Nursing, New York, USA

Purpose The purposes of this study were to develop a taxonomy for detection of errors related to hypertension management and to apply the taxonomy to retrospectively analyze the documentation of nurses in Advanced Practice Nurse (APN) training.

Method We developed the Hypertension Diagnosis and Management Error Taxonomy and applied it in a sample of adult patient encounters ($N = 15,862$) that were documented in a personal digital assistant-based clinical log by registered nurses in APN training. We used Standard Query Language queries to retrieve hypertension-related data from the central database. The data were summarized using descriptive statistics.

Result Blood pressure was documented in 77.5% ($n = 12,297$) of encounters; 21% had high blood pressure values. Missed diagnosis, incomplete diagnosis and misdiagnosis rates were 63.7%, 6.8% and 7.5% respectively. In terms of treatment, the omission rates were 17.9% for essential medications and 69.9% for essential patient teaching. Contraindicated anti-hypertensive medications were documented in 12% of encounters with co-occurring diagnoses of hypertension and asthma.

Conclusion The Hypertension Diagnosis and Management Error Taxonomy was useful for identifying errors based on documentation in a clinical log. The results provide an initial understanding of the nature of errors associated with hypertension diagnosis and management of nurses in APN training. The information gained from this study can contribute to educational interventions that promote APN competencies in identification and management of hypertension as well as overall patient safety and informatics competencies. [*Asian Nursing Research* 2010;4(1):19–31]

Key Words medical error, handheld computers, practice guideline, advanced practice nursing, hypertension, nursing education

ELSEVIER

***Correspondence to:** Eunhee Cho, PhD, MPH, CRNP, RN, Assistant Professor and Researcher, Nursing Policy Research Institute, Yonsei University College of Nursing, 615 Nursing Education Building, 134 Shinchon-Dong, Seodaemoon-Gu, Seoul 120-752, Korea.
E-mail: ehcho@yuhs.ac

Received: February 2, 2010 **Revised:** February 2, 2010 **Accepted:** March 3, 2010

INTRODUCTION

Hypertension is a major cause of death, and increases the risk of other severe diseases, including heart attack, heart failure, stroke and kidney disease (National High Blood Pressure Education Program Coordinating Committee [NHBPEPCC], 2004). Although hypertension is easily recognizable and managed with appropriate treatments, the majority of patients do not know that they have hypertension (Joffres, Hamet, MacLean, L'italien, & Fodor, 2001; Petrella & Campbell, 2005) or demonstrate poor adherence to hypertension treatment (Roberts & Epstein, 2009). An incorrect diagnosis may result in mismanagement and unnecessary treatment or testing. In the absence of appropriate management, uncontrolled blood pressure may lead to other more severe health problems (Kostis, 2007; NHBPEPCC). Advanced Practice Nurses (APNs) play a significant role in identifying and managing patients with hypertension (Roberts & Epstein). Moreover, in our prior study, hypertension was one of the top three diagnoses documented by nurses in APN training (Lee & Bakken, 2008). These studies support the critical need for nurses to gain knowledge and skills regarding hypertension identification and management during their APN training and for the monitoring of knowledge and skills application in clinical practice.

In the clinical practice environment, there has been increased interest in defining medical errors and potential errors as a strategy for promoting patient safety (Chang, Schyve, Croteau, O'Leary, & Loeb, 2005; Kohn, Corrigan, & Donaldson, 2000; Plews-Ogan et al., 2004). However, the terms related to medical errors may be applied differently depending on the identity of users including patients, clinicians, lawyers, patient safety managers, or others (Chang et al.). This lack of common terminologies impedes identification of errors and sharing of error-related data to support patient safety (Chang et al.). Most research on medical errors has focused upon physicians' practice (Phillips, Dovey, Graham, Elder, & Hickner, 2006). Given that the number of APNs such as nurse practitioners, certified nurse midwives, and nurse anesthetists is on the rise, it is important that error taxonomies include APN practice.

Voluntary or anonymous error reporting methods have been used as major resources for research on the detection and characterization of medical errors. However, self-reported errors provide limited information (Mayo & Duncan, 2004; Moore, 1998) due to barriers such as low perceived benefit from reporting, burden of effort to make a report, lack of clarity on what to report, or organizational culture of blame or punishment (Elder, Graham, Brandt, & Hickner, 2007). More recently, electronic sources have demonstrated its usefulness detecting errors (Jacobs, 2007).

As part of the Wireless Informatics for Safe and Evidence-based APN Care project, the faculty at the Columbia University School of Nursing developed a patient safety curriculum (Bakken et al., 2004), measures for assessing patient safety and informatics competencies (Schnall et al., 2008; Yoon, Yen, & Bakken, 2009), and informatics-based tools for supporting safe and evidence-based care (Desjardins, Cook, Jenkins, & Bakken, 2005).

One of the tools that we designed and implemented was a personal digital assistant (PDA)-based clinical log for documentation of clinical encounters (Bakken, John, & Currie, 2008; Jenkins, Hewitt, & Bakken, 2006).The primary motivations for developing the clinical log were to promote students' assessment of their own practice over time and to allow preceptors and faculty to monitor individual students and groups of students as they progressed through their APN training. A secondary motivation was to support retrospective data analyses related to quality of care and patient safety, including error detection. APN students entered de-identified clinical encounters that included patient demographics, student information, medical diagnoses, nursing diagnoses, and a five-part plan of care (including diagnostics, procedures, prescriptions, patient teaching and counseling, and referrals). The display of diagnoses and care plan items available in the log was tailored to the APN specialty. For example, the women's health log did not include male-only diagnoses such as benign prostatic hypertrophy. All data were represented

by standardized terminologies when available; customized terminologies were developed as needed.

Given the importance of hypertension as a significant clinical issue of relevance to APN care, the need for development of error taxonomies inclusive of APN care, and the availability of a data set of encounters from APN students, the purposes of this study were to develop a taxonomy for detection of errors related to hypertension management and to apply the taxonomy to retrospectively analyze the documentation of APN students.

METHODS

This observational study used retrospective analysis to describe hypertension-related errors of nurses in APN training based upon documentation in a clinical log.

Sample and setting

The sample comprised adult patient encounters (patient age ≥18; N=15,862) that had been documented by APN students using the PDA-based clinical log from 2006 to 2008. APN students were enrolled in the following APN specialty programs: acute care nurse practitioner, adult nurse practitioner, family nurse practitioner, oncology nurse practitioner, pediatric nurse practitioner, and women health nurse practitioner. On average, the APN students who documented clinical encounters were in their mid-20s, and more than 85% female. Length of training varied by APN specialty and ranged from 15 to 24 months; the APN students practiced under the supervision of clinical preceptors at hospital-based settings, local clinics and community-based settings throughout the New York City area.

The documentation of encounters using the clinical log was considered an integral part of clinical training and students were trained in its use. APN students (a) assess a patient through physical examination and history-taking, (b) make diagnoses based on the results of assessment, and (c) create plans of care for diagnoses. The clinical log supported documentation of these aspects of the care process (Figure 1). This study was approved by the Columbia University Health Sciences Institutional Review Board.

Development of a taxonomy for describing errors related to hypertension

In order to develop a taxonomy for describing errors related to hypertension management, we reviewed patient safety-related taxonomies and hypertension management guidelines through online databases including MEDLINE, Cumulative Index to Nursing and Allied Health Literature, Cochrane library, and National Guideline Clearinghouse. We selected components of taxonomies that were relevant to the data documented in the clinical log from the Joint Commission (Chang et al., 2005) and Elder (Elder, Vonder Meulen, & Cassedy, 2004). The Joint National Committee (JNC7) on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure guideline (NHBPEPCC, 2004) was used as the source of concepts related to hypertension diagnosis and management. The JNC7 hypertension guideline was developed based on scientific evidence and has been used extensively in the United States and worldwide.

Based on the patient safety components (e.g., misdiagnosis, incomplete diagnosis), one author (NL) extracted hypertension diagnosis and management-related concepts (e.g., criteria of hypertension diagnoses, general classification of blood pressure, treatment criteria for each hypertension diagnosis, contraindication of anti-hypertensive medications, etc.) from the JNC7 hypertension guideline and mapped the concepts to the patient safety components. Then, the author (NL) mapped the patient safety related concepts to standardized terminologies used in the clinical log database. For example, medical diagnoses such as hypertension or asthma were mapped to International Classification of Diseases-Clinical Modification and patient teaching-related plan of care items (e.g., physical activity in lifestyle modification) were mapped to Clinical Care Classification. The resulting Hypertension Diagnosis and Management Error Taxonomy (HDMET; Figure 2) was reviewed by co-authors (EC, SB) and then finalized for the data analysis.

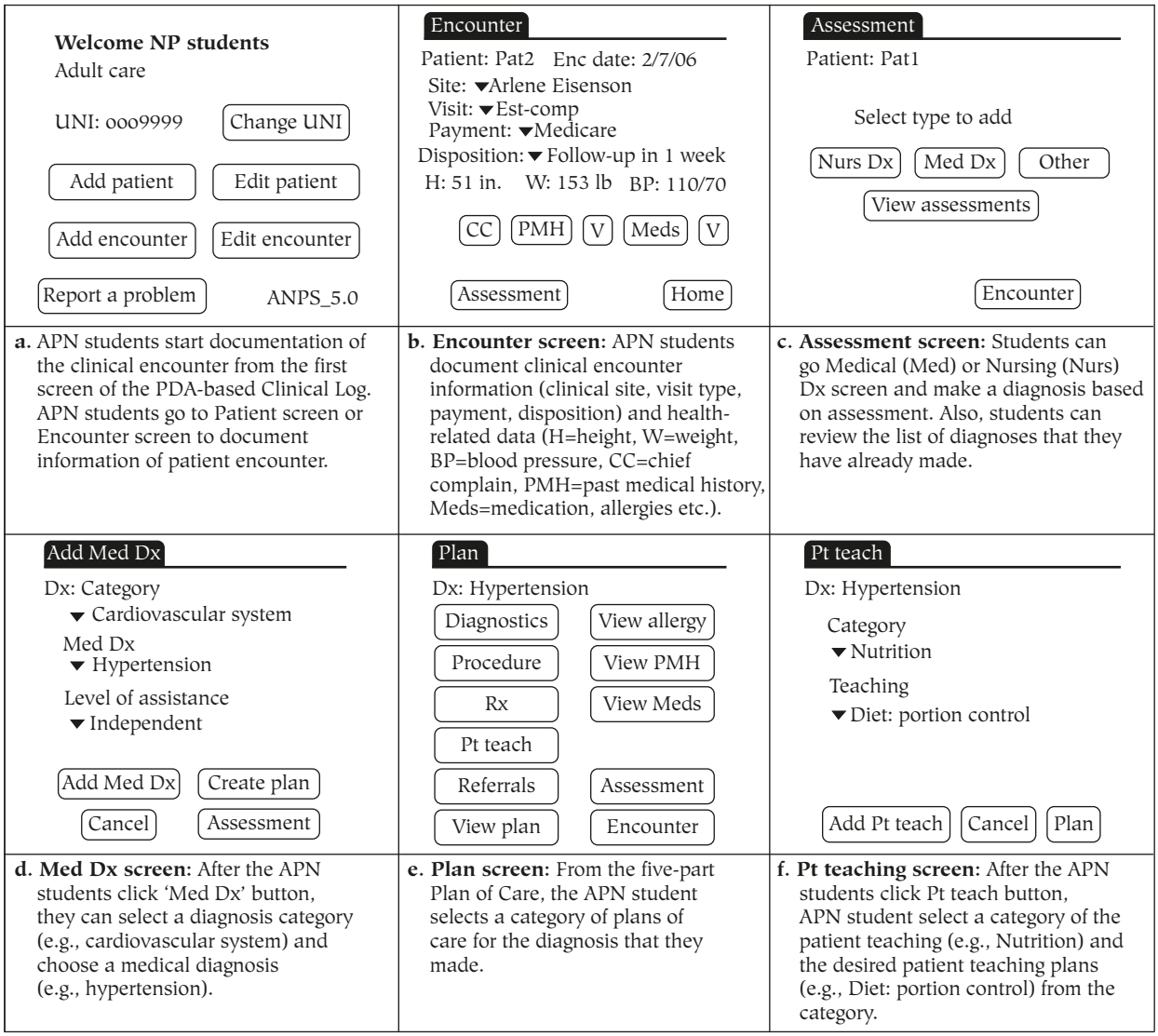

Figure 1. The Personal Digital Assistant (PDA)-based Clinical Log. NP = nurse practitioner; UNI = university network ID; ANPS = adult nurse practitioners; Est-comp = established patient comprehensive; V = view; APN = advance practice nurse; Dx = diagnosis; Rx = prescription, Pt = patient.

The error types are classified into "Diagnosis" and "Intervention". The "Diagnosis" classification is comprised of three sub-classifications:

(a) Misdiagnoses include encounters in which a hypertension diagnosis was documented and the blood pressure (BP) documented was not high (systolic blood pressure [SBP] < 140 mmHg and diastolic blood pressure [DBP] < 90 mmHg) and there was no documentation regarding history of hypertension or use of anti-hypertensive medication;

(b) Incomplete Diagnoses include encounters in which a hypertension diagnosis was documented in the absence of documentation of BP;

(c) Missed Diagnoses include encounters in which a hypertension diagnosis was not documented, but SBP was ≥ 140 mmHg or DBP was ≥ 90 mmHg.

The "Intervention" classification is divided into "Omission of Essentials" and "Intervention Contraindicated". "Omission of Essentials" included prescription of medication, patient teaching, and follow-up

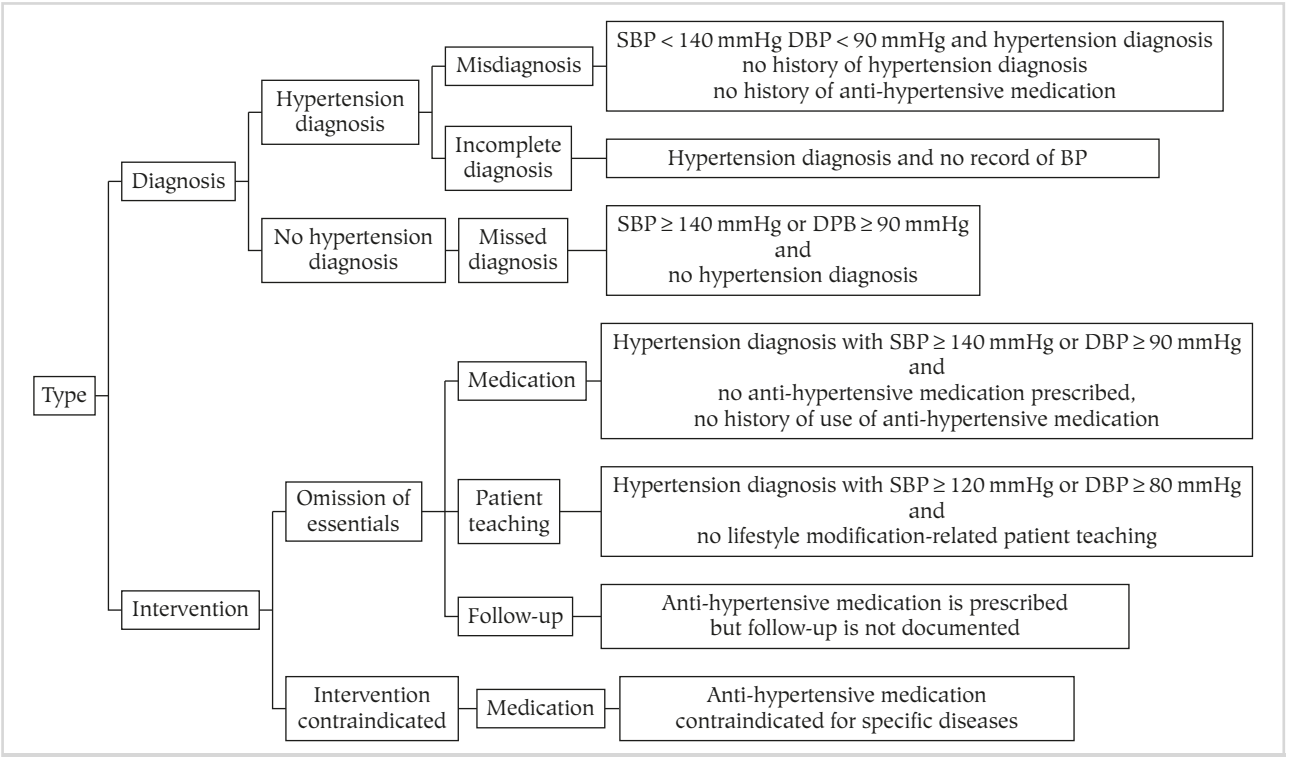

Figure 2. Hypertension Diagnosis and Management Error Taxonomy. SBP = systolic blood pressure; DBP = diastolic blood pressure; BP = blood pressure.

categories. "Omission of Essential Intervention-Medication" includes encounters in which a hypertension diagnosis and high BP (SBP ≥ 140 mmHg or DBP ≥ 90 mmHg) were documented, but no anti-hypertensive medication was selected either in the plan of care or documented in the list of current medications. "Omission of Essential Intervention-Patient Teaching" includes encounters in which a hypertension diagnosis was documented with pre-hypertension or stage 1 or 2 BP (SBP ≥ 120 mmHg or DBP ≥ 80 mmHg), but no lifestyle modification-related patient teaching was documented. Lifestyle modification includes weight reduction, diet-DASH (Dietary Approaches to Stop Hypertension) eating plan, dietary sodium reduction, physical activity and tobacco cessation (NHBPEPCC, 2004). "Omission of Essential Intervention-Follow-up" includes encounters in which anti-hypertensive medication was prescribed, but no recommendation for a follow-up visit was documented.

"Intervention Contraindicated-Medication" indicates encounters in which a type of anti-hypertensive medication contraindicated in patients with specific diseases (e.g., asthma) was documented in the plan of care.

Data retrieval and analysis

Standard Query Language queries were developed to retrieve data associated with the management of hypertension from the Microsoft Access XP project database (Microsoft Corporation, Redmond, WA, USA). In order to analyze errors related to "diagnosis", the entire data set (N = 15,862) was used. Analysis for errors related to "intervention" was conducted with the sub-data set consisting of encounters with hypertension as a current diagnosis (n = 1,834). The following data were retrieved from the data set: (a) encounter information including demographics (age, gender and race) and clinical specialty; (b) patient health-related data including current medical

Table 1

Patient Demographics and Blood Pressure (BP)-related Data in Encounters With Hypertension

Encounters with hypertension (n = 1,834)		
Patient demographic data		
Gender *n* (%)	Male	992 (54.1)
	Female	839 (45.7)
	Missing	3 (0.2)
Age	*M* (*SD*)	56.2 (13.9)
	Median	55.0
	IQR	19.0
Ethnicity *n* (%)	American Indian or Alaska Native	4 (0.2)
	Asian or Pacific Islander	19 (1.0)
	Black, not of Hispanic origin	490 (26.7)
	Hispanic	952 (51.9)
	White, not of Hispanic origin	311 (17.0)
	Other or unknown	58 (3.2)
BP-related data		
SBP (mmHg)	*M* (*SD*)	139.3 (20.70)
	Median	138.0
	IQR	25.0
DBP (mmHg)	*M* (*SD*)	83.39 (22.26)
	Median	82
	IQR	15.0
BP classification *n* (%)	Normal	204 (11.1)
	Pre-hypertension	570 (31.1)
	Hypertension, stage 1	569 (31.0)
	Hypertension, stage 2	367 (20.0)
	Missing BP	124 (6.8)

Note. IQR = inter-quartile range; SBP = systolic blood pressure; DBP = diastolic blood pressure.

diagnoses, past medical diagnoses, medications and BP; and (c) plan of care items including diagnostics, procedure, prescription, patient teaching and referral. Statistical software SPSS 11.0 (SPSS Inc., Chicago, IL, USA) was used to calculate descriptive statistics (including frequency and percentage).

RESULTS

Hypertension diagnosis-related errors in APN student documentation

The data set comprised 15,862 patient encounters documented by 266 APN students which consisted of nurse practitioners from acute care (n=33), adult (n=35), family (n=100), oncology (n=8), pediatric (n=63), and women health (n=27). BP was documented in 77.5% (n=12,297) of encounters, and 21% (n=2,577) had high BP values (SBP ≥ 140 mmHg or DBP ≥ 90 mmHg). Hypertension was not documented in 63.7% (n=1,641) of the encounters, although BP values in these cases were consistent with diagnosis of hypertension. These encounters were categorized as "Missed Diagnosis". Hypertension was documented as a current diagnosis in 11.6% (n=1,834) of encounters and as a past diagnosis in 21.1% (n=3,340) of encounters. Table 1 shows patient demographics and BP-related data for encounters in

Table 2

Diagnoses Categorized by Hypertension Diagnosis and Management Error Taxonomy

Encounters with		*n*
BP record		12,295
High BP (SBP ≥ 140 mmHg or DBP ≥ 90 mmHg)		2,577
Hypertension diagnosis		1,834
Taxonomy	%	*n*
Correct diagnosis	85.7	(1,574/1,834)
SBP ≥ 140 mmHg or DBP ≥ 90 mmHg	51.0	(936/1,834)
Normal BP and	34.7	(636/1,834)
Hypertension diagnosis in past medical history		
History of use of anti-hypertensive medication		
Incomplete diagnosis	6.8	(124/1,834)
Misdiagnosis	7.5	(138/1,834)
Missed diagnosis	63.7	(1,641/2,577)

Note. BP = blood pressure; SBP = systolic blood pressure; DBP = diastolic blood pressure.

which hypertension was documented as a current diagnosis. On average, patients with hypertension were 56.2 years old and more than half (54.1%) were male. Most participants were Black (26.7%) or Hispanic (51.6%), and Medicare/Medicaid beneficiaries (70.5%). Mean SBP was 139.3 mmHg (*SD* = 20.9) and mean DBP was 83.39 mmHg (*SD* = 22.26). BP was not documented in 6.8% of the encounters with a hypertension diagnosis.

Only half of the encounters (*n* = 936) with a hypertension diagnosis had BP values consistent with the JNC7 guideline hypertension criteria (Table 2). Encounters with hypertension diagnoses were classified as "Correct Diagnosis" even when the BP value documented was normal given that hypertension appeared in past medical history or if anti-hypertensive medications were documented. In 6.8% (*n* = 124) of the encounters with a hypertension diagnosis as an assessment diagnosis, BP values were not documented and the encounters were categorized into "Incomplete Diagnosis". About 7.5% of the encounters with hypertension as a current diagnosis had BP values below the criteria of the JNC7 hypertension classification without medical history of hypertension or use of anti-hypertensive medication. They were categorized as "Misdiagnosis"(Table 2).

Anti-hypertensive management-related errors in APN student documentation

The encounters with hypertension were classified by the JNC7 BP classification, and frequencies of anti-hypertensive medications and mean of the number of anti-hypertensive medications documented were analyzed for each hypertension stage (Table 3). In 68.1% (1,249/1,834) of the encounters with hypertension diagnoses, anti-hypertensive medications were documented in the plan of care. No anti-hypertensive medications were documented in 33% (*n* = 188) of the encounters with BP of stage 1 hypertension classification (140 mmHg ≤ SBP ≤ 159 mmHg or 90 ≤ DBP ≤ 99 mmHg), and 23% (*n* = 85) of the encounters with BP of stage 2 hypertension classification (SBP ≥ 160 mmHg or DBP ≥ 100 mmHg); 61.5% (*n* = 168) of these encounters did not have a documented history of use of anti-hypertensive medication. Therefore, 17.9% (168/936) of the encounters with BP values consistent with stage 1 or 2 hypertension were classified into "Omission of Essential Intervention-Medication".

APN students did not document patient teaching related to lifestyle modification in 69.9% (*n* = 1,052) of the encounters with pre-hypertension, stage 1 or stage 2 hypertension. These encounters were classified

Table 3

Anti-hypertensive Medications Documented in Encounters With Hypertension Diagnosis

Encounters by BP classification[a] (*n*)	No. of anti-hypertensive medications documented *n* (%)						*M* (*SD*)
	0	1	2	3	4	5	
Normal (204)	76 (37)	78 (39)	35 (17)	14 (7)	1 (0)	0 (0)	1.52 (0.721)
Pre-hypertension (570)	192 (34)	242 (42)	97 (17)	34 (6)	5 (1)	0 (0)	1.48 (0.714)
Stage 1 (569)	188 (33)	249 (44)	101 (18)	21 (4)	8 (1)	2 (0)[b]	1.46 (0.741)
Stage 2 (367)	85 (23)	167 (45)	79 (22)	30 (8)	6 (2)	0 (0)	1.56 (0.768)
Missing BP (124)	44	54	22	4	0	0	
Total (1,834)	585	790	334	103	20	2	

[a]BP classification of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure guideline defines Normal as SBP < 120 mmHg and DBP < 80 mmHg; Pre-hypertension as 120 mmHg ≤ SBP ≤ 139 mmHg or 80 mmHg ≤ DBP ≤ 89 mmHg; Stage 1 hypertension as 140 mmHg ≤ SBP ≤ 159 mmHg or 90 mmHg ≤ DBP ≤ 99 mmHg; Stage 2 hypertension as SBP ≥ 160 mmHg or DBP ≥ 100 mmHg; [b]0.004%. IQR = inter-quartile range; BP = blood pressure; SBP = systolic blood pressure; DBP = diastolic blood pressure.

Table 4

Omission Errors in Hypertension Management

	Encounter with a hypertension diagnosis	Omission of medication[a]	Omission of patient teaching[a]	Omission of follow-up[b]
BP Stage	*n*	*n* (%)	*n* (%)	*n* (%)
1 Normal BP	204	N/A	N/A	3 (2.3)
2 Pre-hypertension	570	N/A	415 (72.8)	6 (1.6)
3 Stage 1	569	123 (21.6)	394 (69.2)	7 (1.8)
4 Stage 2	367	45 (12.3)	243 (66.2)	1 (0.4)
Missing BP	124			9 (11.4)
3 + 4	936	168 (17.9)		
2 + 3 + 4	1,506		1,052 (69.9)	
Total encounters	1,834			26 (2.1%)

Note. BP = blood pressure; N/A = not applicable. [a]Denominators are the number of encounters with a hypertension diagnosis in each BP stage; [b]denominators are the number of encounters with anti-hypertensive medications prescribed in each BP stage according to the definition of "Omission of Follow-up", where encounters with anti-hypertensive medication prescribed, but no recommendation for a follow-up visit was documented.

into "Omission of Essential Intervention-Patient Teaching. Only 2.1% (26/1249) of the encounters in which anti-hypertensive medication was prescribed lacked follow-up documentation ("Omission of Essential Intervention-Follow-up").

In terms of "Intervention Contraindicated-Medication", nine contraindication concepts were extracted from the JNC7 guideline (Table 5). Of the nine concepts, "angioedema" was not a data element in the clinical log and diuretics were not classified in the same way as that noted in the guideline (e.g., thiazide diuretics or potassium-sparing diuretics); thus not all contraindications could be analyzed with our data set. Table 5 displays the frequencies of contraindicated anti-hypertensive medications documented by APN students in the encounters

Table 5

Concepts of Anti-hypertensive Medication Contraindicated in Specific Disease and Error

Anti-hypertensive medication concepts	Contraindication	Presence of term in database (yes/no)		Encounter with hypertension and this disease *n*	Encounter with contraindicated medication *n*
		Anti-hypertensive medication term	Disease term		
ACE inhibitors	Pregnancy	Yes	Yes	2	0
	Angioedema	Yes	No	N/A	N/A
ARBs	Pregnancy	Yes	Yes	2	0
BBs	Asthma	Yes	Yes	173	20 (11.6%)
	Reactive airways disease	Yes	Yes	1	0
	Second or third degree heart block	Yes	Yes	0	0
Thiazide diuretics	Gout	Yes (broad concept)[a]	Yes	7	0
	Hyponatremia	Yes (broad concept)[a]	Yes	0	0
AA & PSD	Hyperkalemia	Yes (broad concept)[a]	Yes	0	0

Note. ACE = angiotensin-converting enzyme; N/A = not applicable; ARB = angiotensin-receptor blocker; BB = beta-blocker; AA = aldosterone antagonists; PSD = potassium-sparing diuretics. [a]Database had a broader anti-hypertensive medication concept than that of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure guideline (e.g., thiazide diuretics or potassium-sparing diuretics).

with a hypertension diagnosis. Contraindicated anti-hypertensive medication-related errors were identified in 11.6% ($n = 20$) of encounters with diagnoses of hypertension and asthma.

DISCUSSION

We developed and applied the HDMET to analyze APN students' clinical log documentation. Our analysis revealed a number of errors related to hypertension diagnosis and management. BP values were not documented in 22.5% of the 15,862 encounters, including 6.8% of the encounters with a hypertension diagnosis. About 64% of the encounters in which BP values were consistent with the hypertension criteria of JNC7 did not have a hypertension diagnosis. Since our analysis was based upon the BP value from one visit, the actual percent of "Missed Diagnoses" is likely smaller. However, despite the limited BP value from one visit for hypertension diagnosis, APN students should be educated in their training not to overlook even a single high BP in practice which requires APN students to make a plan of care such as follow-up to re-check BP and education for the patient to check BP at home.

Given that patient adherence to therapy for asymptomatic conditions such as hypertension is low (NHBPEPCC, 2004; Roberts & Epstein, 2009), BP documentation is vital for monitoring patient adherence to a therapeutic regimen, as well as diagnosing hypertension and assessing cardiovascular risk. In a number of claims databases or electronic health records, missed BP values or missed diagnostic codes are reported as a problematic issue, which prevents assessment of effective hypertension management

(Halpern et al., 2006). Missing data can result in prescription of a contraindicated hypertensive drug (Goldstein et al., 2001). Given that informatics technologies such as electronic health records (EHR) and clinical decision support systems have demonstrated their effectiveness in decreasing missed clinical information (Haberman et al., 2009; Kim et al., 2006; Lee et al., 2009), the integration of a reminder or an alert system for entering patient BPs into electronic documentation may be a possible strategy for decrease the incidence of missing BP values in APN student documentation.

Although a missed or delayed diagnosis is an important patient safety issue, this area has not been extensively studied (Gandhi et al., 2006; Moskowitz & Nash, 2007). A missed diagnosis could result in delayed treatment which may cause other complications or more severe illnesses. Gandhi et al. reported that an inappropriate follow-up plan was one of the common reasons for missed diagnoses. Reasons for inappropriate follow-up include lack of follow-up, incorrect intervals for follow-up, or no documentation of follow-up (Gandhi et al.).

In terms of errors related to hypertension management, the rate of errors of omission (17.9% for medications and 69.9% for patient teaching) was higher than that of inappropriate treatment (prescribing contraindicated medications). Medication errors are the most frequently reported type of error by health care providers (Plews-Ogan et al., 2004; Suresh et al., 2004), and omission of medication is the most frequent type of medication error (Meurier, Vincent, & Parmar, 1997; Roughead & Semple, 2009). Omission of patient teaching is not typically considered in the patient safety literature, and the omission rate in our study was surprisingly high. Given that patient teaching is an essential component of the APN training, the importance of patient education and effective patient education should be included in the APN curriculum.

There is a dearth of research related to patient safety in APN practice or among students in APN training. Utilization of clinical guidelines is a good strategy for error prevention, but great variation in utilization of clinical guidelines has been reported (Ijas et al., 2009; Martin, 2008). Moreover, research by Martin on family nurse practitioner students' implementation of JNC7 reported that preceptor, availability of guidelines, and personal preference as provider-related barriers, and healthcare costs as healthcare climate factors influenced APN students' implementation of the guideline recommendations during their clinical training. Noncompliance with guidelines results in poorer quality of care and higher cost in hypertension management (Persson, Mjorndal, Carlberg, Bohlin, & Lindholm, 2000). Therefore, faculty members need to educate preceptors and students about the benefits and importance of EBP and facilitate integration of EBP into the APN curriculum.

In terms of methodological approaches, patient safety research based on self-reports of errors shows wide variation in the frequency and type of errors reported by clinicians, which may result from the misunderstanding or misinterpretation of errors due to lack of standardization and agreement on errors (Elder et al., 2004). Our study used informatics methods to develop the taxonomy, and retrieve and analyze data. Therefore, the methods that we applied in this study have the potential to provide more reliable error estimation than research based on self-reports. It is important to use a common language to collect medical errors and compare them in other settings or with other professionals for improving patient safety (Plews-Ogan et al., 2004). The approach using a common taxonomy will facilitate communication with regard to types of errors across APN graduate programs and training hospitals. Although the HDMET was developed in the context of APN clinical training, it may also be applicable to clinical practice in general.

This study has several limitations because we developed the HDMET in the context of the data available in the clinical log knowledge base. The PDA-based clinical log did not capture detailed clinical data such as laboratory data or medication doses because it was designed to support APN student documentation of clinical encounters. The knowledge base of the clinical log also lacked a few terms in the HDMET such as specific diuretics and other

anti-hypertensive medications. Therefore, our analysis could not focus on certain detailed aspects of the JNC7 treatment recommendations. In addition, the criterion BP values for hypertension were limited to a single set that did not take into account comorbidities such as diabetes with other criterion values. The taxonomy can be extended to address these limitations prior to application in other data sets. Another limitation is related to application of the taxonomy. Because the analysis was encounter-based, we were unable to determine if the BP was elevated at more than one visit which is typically considered in a hypertension diagnosis. Our analysis was based upon documentation; therefore, it may underestimate the diagnoses made or interventions delivered because they may have been done without being documented. Lastly, the encounters may not completely reflect the care provided to the patient since the care was provided under supervision of a preceptor who may have contributed additional interventions.

CONCLUSION

The knowledge gained from this study contributes to the understanding of APN students' errors of omission and commission in hypertension detection and management. The results of this study can inform the development of educational interventions that promote hypertension management and patient safety. Furthermore, they can be used to inform the development or redesign of the clinical decision support systems that support detection and management of hypertension.

In order to enhance APN student competencies in patient safety and informatics, integration of a patient safety curriculum and evidence-based informatics systems into APN training is essential (Bakken et al., 2008). When accompanied by analytic tools such as the HDMET, systems such as the clinical log described in this article provide a mechanism by which to identify opportunities for improving student performance in APN training and curriculum.

ACKNOWLEDGMENTS

This research was supported by the Health Resources and Services Administration (D11HP07346) and the National Library of Medicine (G08LM008588).

REFERENCES

Bakken, S., Cook, S. S., Curtis, L., Desjardins, K., Hyun, S., Jenkins, M., et al. (2004). Promoting patient safety through informatics-based nursing education. *International Journal of Medical Informatics, 73*, 581–589.

Bakken, S., John, R., & Currie, L. (2008). Advancing evidence-based practice and patient safety through integration of personal digital assistants into clinical nursing education. *Nursing Outlook, 56*, 38–40.

Chang, A., Schyve, P. M., Croteau, R. J., O'Leary, D. S., & Loeb, J. M. (2005). The JCAHO patient safety event taxonomy: A standardized terminology and classification schema for near misses and adverse events. *International Journal for Quality in Health Care, 17*, 95–105.

Desjardins, K., Cook, S. C., Jenkins, M. L., & Bakken, S. (2005). Effect of an Informatics for evidence-based practice curriculum on nursing informatics competencies. *International Journal of Medical Informatics, 74*, 1012–1020.

Elder, N. C., Graham, D., Brandt, E., & Hickner, J. (2007). Barriers and motivators for making error reports from family medicine offices: A report from the American Academy of Family Physicians National Research Network (AAFP NRN). *Journal of the American Board of Family Medicine, 20*, 115–123.

Elder, N. C., Vonder Meulen, M., & Cassedy, A. (2004). The identification of medical errors by family physicians during outpatient visits. *Annals of Family Medicine, 2*, 125–129.

Gandhi, T. K., Kachalia, A., Thomas, E. J., Puopolo, A. L., Yoon, C., Brennan, T. A., et al. (2006). Missed and delayed diagnoses in the ambulatory setting: A study of closed malpractice claims. *Annals of Internal Medicine, 145*, 488–496.

Goldstein, M. K., Hoffman, B. B., Coleman, R. W., Tu, S. W., Shankar, R. D., O'Connor, M., et al. (2001). Patient safety in guideline-based decision support for hypertension management: ATHENA DSS. *Proceedings : A conference of the American Medical Informatics Association*, 214–218.

Haberman, S., Feldman, J., Merhi, Z. O., Markenson, G., Cohen, W., & Minkoff, H. (2009). Effect of clinical-decision support on documentation compliance in an electronic medical record. *Obstetrics and Gynecology, 114*, 311–317.

Halpern, M. T., Khan, Z. M., Schmier, J. K., Burnier, M., Caro, J. J., Cramer, J., et al. (2006). Recommendations for evaluating compliance and persistence with hypertension therapy using retrospective data. *Hypertension, 47*, 1039–1048.

Ijas, J., Alanen, S., Kaila, M., Ketola, E., Nyberg, S., Valimaki, M. A., et al. (2009). Primary care guidelines: Senior executives' views on changing health centre practices in hypertension treatment. *Scandinavian Journal of Primary Health Care, 27*, 202–207.

Jacobs, B. (2007). Electronic medical record, error detection, and error reduction: A pediatric critical care perspective. *Pediatric Critical Care Medicine, 8*(Suppl. 2), S17–S20.

Jenkins, M. L., Hewitt, C., & Bakken, S. (2006). Women's health nursing in the context of the National Health Information Infrastructure. *Journal of Obstetrical, Gynecological, and Neonatal Nursing, 35*, 141–150.

Joffres, M. R., Hamet, P., MacLean, D. R., L'italien. G. J., & Fodor, G. (2001). Distribution of blood pressure and hypertension in Canada and the United States. *American Journal of Hypertension, 14*, 1099–1105.

Kim, G. R., Chen, A. R., Arceci, R. J., Mitchell, S. H., Kokoszka, K. M., Daniel, D., et al. (2006). Error reduction in pediatric chemotherapy: Computerized order entry and failure modes and effects analysis. *Archives of Pediatrics & Adolescent Medicine, 160*, 495–498.

Kohn, L. T., Corrigan, J. M., & Donaldson, M. S. (2000). *To Error is Human: Building a Safer Health System*. Washington, DC: National Academy.

Kostis, J. B. (2007). The importance of managing hypertension and dyslipidemia to decrease cardiovascular disease. *Cardiovascular Drugs and Therapy, 21*, 297–309.

Lee, N. J., & Bakken, S. (2008). Utility of a PDA-based advanced practice nurse student clinical log to detect possible diagnostic errors related to hypertension management. *Proceedings: A conference of the American Medical Informatics Association*, 1020.

Lee, N. J., Chen, E. S., Currie, L. M., Donovan, M., Hall, E. K., Jia, H., et al. (2009). The effect of a mobile clinical decision support system on the diagnosis of obesity and overweight in acute and primary care encounters. *Advances in Nursing Science, 32*, 211–221.

Martin, F. (2008). Why we do what we do: Implementation of practice guidelines by family nurse practitioner students. *Journal of the American Academy of Nurse Practitioners, 20*, 515–521.

Mayo, A. M., & Duncan, D. (2004). Nurse perceptions of medication errors: What we need to know for patient safety. *Journal of Nursing Care Quality, 19*, 209–217.

Meurier, C. E., Vincent, C. A., & Parmar, D. G. (1997). Learning from errors in nursing practice. *Journal of Advanced Nursing, 26*, 111–119.

Moore, J. D., Jr. (1998). Outcomes. Getting the whole story: The way medication errors are reported affects the results. *Modern Healthcare, 28*, 46–46.

Moskowitz, E. J., & Nash, D. B. (2007). The quality and safety of ambulatory medical care: Current and future prospects. *American Journal of Medical Quality, 22*, 274–288.

National High Blood Pressure Education Program Coordinating Committee. (2004). *The seventh report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure*. Retrieved July 1, 2007, from http://www.nhlbi.nih.gov/guidelines/hypertension/

Persson, M., Mjorndal, T., Carlberg, B., Bohlin, J., & Lindholm, L. H. (2000). Evaluation of a computer-based decision support system for treatment of hypertension with drugs: Retrospective, nonintervention testing of cost and guideline adherence. *Journal of Internal Medicine, 247*, 87–93.

Petrella, R. J., & Campbell, N. R. (2005). Awareness and misconception of hypertension in Canada: Results of a national survey. *The Canadian Journal of Cardiology, 21*, 589–593.

Phillips, R. L., Dovey, S. M., Graham, D., Elder, N. C., & Hickner, J. M. (2006). Learning from different lenses: Reports of medical errors in primary care by clinicians, staff, and patients: A project of the american academy of family physicians national research network. *Journal of Patient Safety, 2*, 140–146.

Plews-Ogan, M. L., Nadkarni, M. M., Forren, S., Leon, D., White, D., Marineau, D., et al. (2004). Patient safety in the ambulatory setting. A clinician-based approach. *Journal of General Internal Medicine, 19*, 719–725.

Roberts, M. E., & Epstein, B. J. (2009). Optimizing management of hypertension with combination therapy: Considerations for the nurse practitioner. *The Journal of Cardiovascular Nursing, 24*, 380–389.

Roughead, E. E., & Semple, S. J. (2009). Medication safety in acute care in Australia: Where are we now?

Part 1: A review of the extent and causes of medication problems 2002-2008. *Australia and New Zealand Health Policy, 6*, 18.

Schnall, R., Stone, P. W., Currie, L. M., Desjardins, K., John, R., & Bakken, S. (2008). Development and initial validation of a self-report instrument to measure patient safety attitudes, skills, and knowledge (PS-ASK). *Journal of Nursing Scholarship, 40*, 391–394.

Suresh, G., Horbar, J. D., Plsek, P., Gray, J., Edwards, W. H., Shiono, P. H., et al. (2004). Voluntary anonymous reporting of medical errors for neonatal intensive care. *Pediatrics, 113*, 1609–1618.

Yoon, S., Yen, P-Y., & Bakken, S. (2009). Psychometric properties of the self-assessment of nursing informatics bompetencies scale. *Studies in Health Technology and Informatics, 146*, 546–550.