Bacheloroppgave

NTNU
Norges teknisk-naturvitenskapelige universitet
Fakultet for medisin og helsevitenskap
Institutt for samfunnsmedisin og sykepleie

Anonym

Pharmacogenomics in nursing

Litteraturbachelor
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Bacheloroppgave i Sykepleie
Juni 2021

NTNU
Kunnskap for en bedre verden

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Sammendrag

Sykepleiefunksjoner utvikler seg kontinuerlig for å oppfylle kravene i det moderne samfunnet. Fremskritt i den pågående genomiske tiden kan bidra med nye verktøy og kompetanser for en mer individualisert sykepleie. Mange studier har vist fordelene med å integrere farmakogenomikk i helsehjelpen.

Hensikten med litteraturstudien var å belyse på hvilke måter kunnskap om farmakogenomikk bidrar til at sykepleier øker medisinske behandlingseffekt. Hendersons perspektiver i sykepleie og teori om kunnskapstranslasjon var valgt som teoretiske plattfom. Datainnsamling ble gjort gjennom systematisk søk på databaser som CINAHL Complete, MEDLINE (Ovid) og Oria NTNU.

Ni vitenskapelige studier (seks originale forskningsartikler og tre litteraturstudier) ble til slutt valgt etter kritiske vurderinger. Disse studiene viste at genetiske variasjoner fører til forskjellige bivirkninger og medikamenteffekt hos ulike pasienter. Sykepleiere har brukt farmakogenomikk ved å utføre gentest, informere og veilede pasienter. Farmakogenikk er anbefalt som nye briller, teknologi og kompetense i sykepleie.

Denne studien konkluderer at dagens sykepleiere kan anvende farmakogenomikk i sykepleieprosessens ulike faser. Sykepleiere kan inkludere kunnskap om farmakogenomikk ved administrasjon av medisin og evaluering av bivirkninger hos den enkelte pasient. Sykepleiere kan også anvende farmakogenomikk ved advokering for sine pasienter. Undervisning om farmakogenomikk til pasienter og deres omsorgspersoner kan hjelpe dem å ta bedre vare på seg selv. Sist, men ikke minst, kan sykepleiere utføre forskning innen farmakogenomikk som en måte å lede og utvikle sin kliniske praksis, og derved forbedre kvaliteten på sykepleie og helsetjeneste.

Nøkkelord: sykepleie, farmakogenomikk, Henderson, kunnskapstranslasjon.

Abstract

Nursing functions are constantly evolving to meet the requirements of modern society. Advances in the ongoing genomic era may equip nurses with new tools and competencies to provide a more individualised patient care. Many studies have demonstrated the benefits of integrating pharmacogenomics in various health care settings.

This literature study explores how knowledge on pharmacogenomics helps nurses to improve patient outcomes. Henderson's perspectives in nursing and theory of knowledge translation provide the paper's theoretical frameworks. Systematic search on databases such as CINAHL Complete, MEDLINE (Ovid) and Oria NTNU.

Six original research and three literature reviews were finally slected. These studies demonstrate that genetic variations lead to different side effects and drug efficacy among patients. Nurses have been using pharmacogemics in nursing care through conducting genetic testings, informing and educating patients. Pharmacogenomics is suggested using as nurses' new lens, technology, and competency.
The paper argues that today's nurses may employ pharmacogenomics in various phases of the nursing process. Nurses may include knowledge on drug-gene relations to administer, monitor, and evaluate patients' responses related to medication treatment. Furthermore, nurses can advocate for rights of their patients to benefit better outcomes from pharmacogenomics. Nurses may also educate pharmacogenomics to patients and their caretakers to take better care of themselves. Last, but not least, nurses can conduct research in pharmacogenomics as a way to lead and develop their clinical practice and thereby improve quality of healthcare and patient outcomes.

Keywords: nursing, pharmacogenomics, Henderson, knowledge translation, patient outcomes.

Preface

Genetics

My father's in my fingers, but my mother's in my palms.
I lift them up and look at them with pleasure –
I know my parents made me by my hands.

[…]

Sinéad Morrissey, 2005

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1. Introduction

1.1 Pharmacogenomics and nursing

Nurses have a key responsibility and unique position in administrating pharmacotherapy (Khan 2020; Powell et al., 2020; Sink & Scardina, 2020). This has been an integral part of the nurses' professional role from the beginning of nursing when Florence Nightingale gave medicines to soldiers to help them overcome their injuries (Wilbeck, 2016). Pharmacotherapy means the use of medicine (chemicals) to affect the organs' functions. It is desired to use medication that is as precise as possible (Wyller, 2019). Inappproriate doses lead to 80% of all adverse events (Albriktsen, 2019, slide 48).

While it is the responsibility of doctors to prescribe and adjust the pharmacotherapy, it is the nurses who are at the bedside of the patients, administer, assess drug effectiveness, allergies, side effects, and adjust drip rates every day (Coyle, 2017; Powell et al., 2020; Sink & Scardina, 2020). It is important that practitioners who are involved in medication administration have clear understandings of the concepts in pharmacology to ensure patient safety (Khan, 2020, p. 28).

During my surgical practical training in nursing, I experienced that patients, who underwent for instance laparotomy, were mostly prescribed oxycondon (OxyContin, OxyNorm) and/or tramadol in addition to paracetamol and/or ibuprofen as pain relief. Some patients needed to take more analgesic types than others. I wonder if genetic tendency could have been a part of the explanation for the pharmacotherapy's ineffectiveness.

Patients' responses to drugs vary and are dependent on many factors, among which is the patient's genetic make-up (Atbriksen, 2019, slide 45). In recent years, there has been an increasing interest in pharmacogenetics on individual responses to drugs (Romskaug, 2020). Genetic variations can help predict adverse reactions and drug efficacy which allow patients and doctors to make informed decision (Dodson, 2017). It is estimated that genetic variations are accounted for 20-95% of variations in drug responses (Rahma et al., 2020). Pharmacogenomic information has been used to guide therapies in many healthcare areas: paediatrics, psychiatry, rheumatology, gastroenterology, dermatology, endocrinology, infectious diseases, haematology, cardiology, neurology, urology, and oncology (Colye, 2017).

Genomics is also changing the profession of nurses who made up the largest global contingent of health providers (Calzone et al., 2012; Calzone et al., 2013; Jenkins et al., 2005). However, studies have revealed limitations in genomic competency and genomic applications in the nursing practice worldwide (Calzone et al., 2012; Rahma et al., 2020).

1.2 Relevant background knowledge and theories

Pharmacogenomics

Pharmacogenomics refers to the study of how genetic differences in the human genome (all the genetic information in a person) affects individual predisposition and response to drugs (Foleu & Quigley, 2010; Kaye et al., 2020). Pharmacogenetics refers to the use of genetic data to guide drug therapies (Smith et al., 2018). This paper uses the two terminologies interchangeably.

Genetic polymorphism are variations in the structure of the genes. Polymorphism may change an original gene to an allele. The gene variations or polymorphism may affect pharmacokinetics (how the body affects the drugs) and pharmacodynamics (how the drugs affect the body) in the body (Sekhri & Cooney, 2017).

Drug metabolism
In the pharmacokinetics process, enzymes transform drugs to metabolites. This is to convert fat-soluble drugs to a more water-soluble structure, thereby detoxifying the drugs. This process is called biotransformation and is achieved by two phases. Phase 1 metabolism is carried out by the large group of enzymes known as cytochrome P450 (CYP450) (Khan, 2020, p. 36).

CYP450 is the most well-studied group of drug metabolising enzymes. This enzyme family comprises over 50 enzymes, all of which are highly polymorphic. They result in the vast interindividual differences in drug metabolism (Ting & Schug, 2016). However, only few enzymes are involved in metabolism of over 90 % of current therapeutic drugs (Sink & Sardina, 2020). Cytochrome P450 2D6 (CYP2D6) is one of the most investigated cytochromes. It is responsible for the metabolism of around 25% of all currently clinical used drugs (Ting and Schug, 2016; Romskaug et al., 2020). While CYP3A4 is said to be the most important enzyme as it is involved in metabolism of 50-65% of all prescribed medications (Khan, 2020, p.36).

Drug metabolism can have important consequences on the drugs' therapeutic effects or its toxicity. Early assessment of metabolic pathways helps to predict individual variation in drug response and elimination due to metabolism and therefore enhances a more personalised medication and dose (Gasser, 1999; Smith et al. 2018, Ting & Schug, 2016).

Pharmacogenetic testing is a diagnostic tool which has been regarded as an important approach to personalised healthcare (Lea et al., 2011; Nielsen et al., 2014; Smith et al., 2018; Ting & Schug, 2016). Intravenous puncture or buccal swab are used to collect patients' DNA. This allows identification of polymorphisms in the patient's cytochrome 450 enzymes. The testing can be regarded as patient genotyping (Howington et al., 2011). Genotype is understood as the individual genetic identity that does not show as outward characteristics, versus phenotype are the corresponding observable characteristics.

The gene-drug relationship
Patients can be generally categorised into four CYP2D6-metabolising phenotype subgroups based on their CYP2D6 genotype (Romskaug, 2020). Poor metabolisers (PMs) are individuals with a decrease or absence of the CYP2D6 metabolising enzymes, thus

they metabolise medications slowly or not at all. They are likely to experience overdosing and more side effects. Intermediate metabolisers (IMs) have a slower than normal metabolism, they can experience less dramatic side effects. Extensive metabolisers (EMs) are individuals with regular metabolism, corresponding to the majority of the population. They benefit medication effectiveness from normal doses. Ultrarapid metabolisers (UMs) metabolise medications rapidly and therefore may not get the intended benefits of normal dose (Sink & Scardina, 2020, p.377).

The table below simplifies the relationship between genotype and its anticipated impact on drugs based on presentation by Prows (2011, s.46). This can be used to understand the implications of individual genetics on the efficacy or inefficacy of pharmacotherapy.

Table 1.1 The relationship between different metabolisers and their anticipated impact on drugs.

Genotype predicted phenotype	**Anticipated impact on Active Drug**	**Anticipated impact on Prodrug***
Poor/ slow metaboliser (PM)	Decreased efficiency in converting active drug to inactive metabolites. This increases risk for higher levels of active drugs and clinical toxicity.	Inactive prodrug cannot be converted to active metabolites. If prodrug has no therapeutic properties, then patients will experience lack of efficacy despite drug dose increases.
Intermediate metaboliser (IM)	Similar to poor metabolisers.	Decreased efficiency in converting prodrug to metabolites. Patients may not experience adequate effects when prescribed standard maintenance doses.
Extensive metaboliser (EM)	Standard doses give effectiveness without or with minimal side effects.	Efficiency in converting prodrug to active metabolites without or with minimal side effects.
Ultra Rapid metaboliser (UM)	Increased efficiency in converting active drug to inactive metabolites. Patients will face risks for lower effectiveness of standard dose.	Prodrug is overly converted to active metabolites. Patients face risks for toxicity from high levels of active metabolites.

Source: Adapted from Prows (2011, p.46)

*Prodrug is a pharmacologically inactive form of an active drug. It is used when a pharmacolocally active drug has poor solubility and permeability. Chemicals or enzymes release prodrug to active drug (Cho & Yoon, 2018).

Henderson's perspectives in nursing

Henderson's concept of basic nursing has been widely cherished over the last 60 years. She has defined the nurse's unique function as follows:

> "to assist the individual, sick or well, in the performance of those activities contributing to health or its recovery (or to peaceful death) that the person would perform unaided given necessary strength, will or knowledge. And to do this in such a way as to help the individual gain independence as rapidly as possible."
>
> (Henderson, 1997, p.22)

Henderson (1995, p.22) also comments that her definition of nursing is open for interpretation in various settings. One of them is that the nurses' roles can overlap the roles of physicians in clinical field. This is particularly relevant when nurses work alone. In her book (1997), she states that the provided nursing needs to be modified accordingly to patients' conditions and pathological states. Post-operative states, persistent or intractable pain, anxiety, and depression are among these conditions. The nurse is the master of his/her work. He/she has to take initiatives and controls. It is also the nurse's role to carry out the therapeutic plans as initiated by the physician. The nurse is a member of the medical team and has a mutual responsibility to help each other to plan and carry out the treatment with the patient served as the central figure. A nurse's role is a shifting one: it changes with time and accordingly to situations.

The nursing process includes six stages: identifying patient-client's problems, collecting data, making plans to solve it, implementing the plans and finally evaluate their effectiveness. Henderson (1995, p. 200-201) argues that the nursing process is not really a process of nursing, but rather an analytical process which should be used by all healthcare providers when these providers aim at a problem-solving approach to the patient-client's problem.

Henderson continues that the nursing process has evolved from the movements, among others, to "individualise nursing care" and to "establish the right of the nurse to an independent, professional and unique role". Individualised care or personalised care of the patient-client dated back from the beginning of nursing. Patients' background opinions, wishes and satisfactions stay in the centre of the treatment plans and implementations.

Knowledge translation

Knowledge can be explained by its synonyms such as science, know-how, learning, insight, expertise, proficiency, experience (Kristoffersen, 2016, p. 140).

According to Lockwood and Hopp (2016, p.319-320), knowledge translation in healthcare is described as a process-driven approach to employ knowledge based upon the synthesis, dissemination, and exchange. The end point is to improve health, health services and products, and strengthen the healthcare system. Nurses have been familiar with these activities. The synthesis for instance, is the systematic review of literature or development of evidence-based guidelines. Knowledge translation can also be understood as the movement of knowledge from one sphere or domain to another. The full spectrum

of knowledge translation derives from unmet need for knowledge to discovery, to clinical application and finally clinical/political action. Throughout history, this process has led to major clinical applications.

Futhermore, Lockwood and Hoop (2016, p.320) also comment that the process of knowledge translation shares similar discipline with evidence-based healthcare. This latter process is derived from translating of clinical problems or need to an answerable question (step 1), comprehensive search for best available practice (step 2), critical appraisal of evidence (step 3), to implementing findings as best practice (step 4), and evaluating the impacts and outcomes of the new practices (step 5). However, knowledge translation puts more weight on the movement of nursing knowledge across the gap between clinical application and clinical/political action with a nursing practice focus.

Doane and Varcoe (2008) suggest to reenvision knowledge translation from evidence-based to inquiry-based practice. Within nursing, this means that the process "involves a conscious tuning into this implicit, intricate knowing process as a way of being in nursing situations" (Doane & Varcoe, 2008).

The World Health Organisation (cited in Doane et al. 2015) has declared that a "strong emphasis should be placed on translating knowledge into action to improve public health by bridging what is known and what is actually done". Knowledge translation is a joint effort where research, practicians and policy maker mobilise knowledge for better patient care and health outcomes (Doane et al., 2015).

1.3 Research question

The objective of this present paper is to explore the use of pharmacogenomics in healthcare and its implications for the nursing practice. Nurses can find themselves facing this issue where for instance post-surgical patients are dissatisfied with their pain management or show symptoms of ineffective pain relief. These are examples of situations where the pivotal roles of nurses in pharmacotherapy emerge. Knowledge on pharmacogenomics is the focus of this study.

In this paper, pharmacogenomic knowledge is limited to the use of cytochrome P450 (CYP) enzyme, particularly CYP2D6 enzyme, in pharmacotherapy. The paper excludes other drug metabolising enzymes, drug transport proteins, receptors, and drug to drug reactions. Patient outcomes in this paper focus on the adverse effects and drug efficacy. Studies on pharmacogenomics will be mainly drawn from the contexts of pain management, cancer care and mental health. The term patient(s) and patient-client(s) are used interchangeably to underline patients' active roles in the healthcare treatment. The research question is as follows:

In what ways does knowledge on phamacogenomics help nurses improve patient outcomes?

2. Method

Vilhelm Aubert, one of Norway's leading social researchers and internationally acclaimed sociologists, provides a concise and solid definition of method. It reads:

> "A method is a way to proceed, a means to solve problems and arrive at new knowledge. Any means serve this end belong to the arsenal of methods."
>
> (Aubert, 1973, p.77)

This paper used the method of literature study to explore phamacogenomics in nursing. Literature study utilises knowledge from existing theories, research studies and reviews (Dalland, 2017, p.207). I applied the process of data synthesis presented by Evans (2002). This process comprises of four distinct phases. The first three phases will be presented in this method section, whereas findings from the last phase will be presented in the result section.

Phase 1: "Gather the sample"

Databases

Systematic search was conducted using databases provided by NTNU University Library, Subject page for medicine and health. These following databases were purposely chosen: Cinahl Complete (which is claimed as the world's most comprehensive database for nursing and health-related journals), Oria, Medline, EMBASE (which claims to have strong coverage of pharmacological topics), Cochrane, SweMed+. The latter three databases were omitted eventually due to duplicates (in the case of EMBASE) or all records did not fit in the inclusion criteria (in the case of records retrieved by Cochrane and Swemed+).

Search terms included: "pharmacogenomics", "pharmacogenetics", nurs*, "pain management". MeSH was used to identify equivalent academic terms. This resulted in more search terms like "pain relief", "pain reduction", "pain control". The paper's original focus was on pain management and was eventually expanded to other domains. This was due to two main reasons. Firstly, I aimed at articles written by nurse scholars. By expanding the care settings to oncology and mental health, more relevant articles were found. Besides being of my personal interests, pharmacogenomics implications in these care settings have been well-studied in the past decades to my knowledge. Secondly, this will also prepare myself better for general nursing which I will start to work with after graduation. Consequently, more search terms were added, namely "oncology" and "mental health".

"Select the sample"

I determined inclusion and exclusion criteria beforehand. They were based the assignment's requirements and Dalland's suggestions on method (2017, p.211)

Inclusion criteria:

- Research articles: empirical studies, qualitative studies, original articles, literature reviews. The inclusion of various research methods is meant to follow Evans' (2002,

p.22) argument: Numerical data alone is not adequate to explore phenomena in nursing profession.
- Peer-reviewed articles.
- Years of publication: 2011-current.
- Relevance to research question. Based on Dalland (2017, p.156), an article is relevant to the research question when it contains elements that can shed light on the issue in question and how I plan to use these elements in my literature study.

Exclusion criteria:

- Articles written in other languages than English, Norwegian and Vietnamese.
- Articles that focus on drug metabolising enzymes other than CYP450, drug transport proteins, receptors, and drug to drug reaction, and drug-drug interactions.
- Articles whose full texts are not available.

Search terms, records and results are presented in table 2.1

Table 2.1 Search results

Databases/ Date	Search ID	Search terms	Limit to	Search results	Chosen articles
CINAHL Complete 17.04.2021	S1.	(MH «Pharmacogentics» OR «Pharmacogenomics)		2132	
	S2.	Nurs*		968932	
	S3.	(MH «Pain Management» OR «pain management» OR MH«Postoperative Pain)		42255	
	S4.	MH «Postoperative Pain» OR «pain relief»)		33495	
	S5	MH «Postoperative Pain» OR «pain reduction»		24133	
	S6	«pain control» OR MH«Pain management)		14204	
	S7	S3 OR S4 OR S5 OR S6		57053	
	S8	S1 AND S7	2011-2021	43*	1 **(A)**
Included article A) Aroke & Kittelsrud (2020). Pharmacogenetics of Postoperative Pain Management: A Review. AANA Journal, 88(3), 229–236					
Oria NTNU 17.04.2021	S1	"pharmacogenomics" OR "pharmacogenetics"			
	S2	"pain management" OR "pain reduction" OR "pain relief" OR pain control			

	S3	nurs*			
	S4	S1 AND S2 AND S3	2011-21 Peer-reviewed	447*	1 **(B)**
Included article B) Dagostino et al. (2018). CYP2D6 genotype can help to predict effectiveness and safety during opioid treatment for chronic low back pain: Results from a retrospective study in an Italian cohort. *Pharmacogenomics and Personalized Medicine*, 11, 179–191.					
Manual search on Oria NTNU 17.04.2021					1 ©
Included article C) Hu et al. (2018). "A Theoretical Framework for Interaction of Nursing Discipline with Genetics and Genomics." *International Journal of Nursing Sciences* 5(4):336–42.					
CINAHL Complete 26.04.2021	S1	(MH "Pharmacogenetics") OR ""pharmacogenetics""		2752	
	S2	"nurs*" OR (MH "Nurse Authors")		970 367	
	S3	S1 AND S2		120*	3 (**D, E, F**)
Included articles D) White et al. (2019) Pharmacogenomics and psychiatric nursing. *Issues in mental health nursing* 40.2: 194-198. E) Moraes et al. (2020). Nurse empowerment through Pharmacogenetics. *Revista Latino-Americana de Enfermagem*, 28. F) Prows (2011). Infusion of Pharmacogenetics Into Cancer Care. *Seminars in Oncology Nursing*, 27(1), 45–53.					
CINAHL Complete 13.05.2021	S1.	(MH «Pharmacogentics» OR «Pharmacogenomics)		2137	
	S2.	Nurs*		970367	
	S3	psychiatric		95728	
	S4	Mental health		156104	
	S5	S3 OR S4		222551	

	S6	S5 AND S1 AND S2		12*	1 **(G)**
Included article G) Kierce et al. (2019). Use of PHQ-9 and pharmacogenetic testing in clinical practice. *Journal of the American Association of Nurse Practitioners*, 31(9), 497-501.					
MEDLINE (Ovid) 20.05.2021	S1	"pharmacogenomics".mp. or exp Pharmacogenetics/		15363	
	S2	nurs*.mp.		775891	
	S3	S1 AND S2		137*	2 (H, I)
Included article H) Dodson (2014). Knowledge and attitudes of oncology nurses regarding pharmacogenomic testing. *Clinical Journal of Oncology Nursing*, 18(4), E64–E70. https://doi.org/10.1188/14.CJON.E64-E70 I) Cheek et al. (2015). Pharmacogenomics and Implications for Nursing Practice. *Journal of Nursing Scholarship*, 47(6), 496–504. https://doi.org/10.1111/jnu.12168					

*Articles whose titles were screened. Duplicates were omitted.

This process of selecting the sample was made in three steps. In step 1, I screened all titles from yielded results to consider if an article may be relevant to the research topic. In step 2, I read abstracts of these potential articles and selected articles based on inclusion and exclusion criteria. Only a few articles remained after this step.

Lastly in step 3, I read these selected articles in full texts to finalise which articles would be included. I considered these articles with focus on these following elements:

- The research follows IMRAD structure (Introduction- Method- Result- Discussion).
- The methodology seems thorough and appropriate to answer the research problem.
- New knowledge that the article presents.
- The language is professional and relevant.
- Statements of conflicts of interest: I read careful if and how the research is sponsored by someone interested in the outcome. This is relevant for the paper's topic due to the potential involvement of pharmaceutical industry which may lead to research bias.

Phase 2: "Identify key findings"

I read and re-read chosen articles to develop deeper understandings of the reported issues. I made attempts to understand the studies' findings to evaluate how they could be incorporated into my paper's phenomenon of interest (pharmacogenomics in nursing). Subsequently, key findings were intentionally collected from each study.

I purposely chose to generate data from a wide range of study types, which aimed at involving diverse populations and circumstances. According to Evans (2002, p. 25), this will enable "a composite of descriptions to capture the essence of phenomenon". Sherwood (in Evans 2002, p.24) comments that the greater degree of this composite, the more generalisable results to nursing practice.

Phase 3: "Relate themes across studies"

In phase 3, relevant findings from chosen studies were identified. Differences and similarities between these findings were explored and grouped into similar or different themes. The table below presents identified themes and their corresponding articles.

Table 2.2 Identified themes and their corresponding articles

Themes	Articles
Pharmacogenomics implications in healthcare	A, B, D, E, F, G, H, I
The importance of pharmacogenomic testing	A, B, C, D, E, F, G, H, I
Employing pharmacogenomics as nurses' new lens, technology, and competency	C, E, H, I

Phase 4: "Describe the phenomenon"

Following Evans (2002), a detailed description of each theme is presented with reference to its original study to check its accuracy in this phase. This paper aims to not only summarise and describe the results reported in the included articles, such as in a descriptive synthesis, but also re-interpret these results so that they are more generalisable to nursing practice (Evans, 2002, p.24). This last phase will be accounted in the following result section.

3. Results

3.1 Presentations of results

Table 3.1 lists the included articles, summaries of their objectives, methods, and results (only objectives and results which are relevant to the research question are listed), and their relevance to the research question.

Table 3.1: Overview of selected articles

References	Objectives, Research question	Methods	Results	Comments a relevancies to my research question
A) Aroke & Kittelsrud (2020). Pharmacogenetics of Postoperative Pain Management: A Review. *AANA Journal*, *88*(3), 229–236.	Examine evidence of the genetic differences that effect patients. Reponses to medications frequently used in postoperative pain management.	A review	Analgesic efficacy and adverse effects of pain medications depends on (among others) their rate of metabolism by CYP enzymes. Codein and tramadol are not recommended in CYP2D6 poor metabolisers and ultrarapid metabolizers.	The article provides evidence that pharmacogenomics can be used to help reduce side effects and increase postoperative pain management. Nurses may use this knowledge when administrating common analgesics such as tramadol, codein, oxycodone, hydrocodone, fetanyl. Written by nurses.
B) Dagostino et al. (2018). CYP2D6 genotype can help to predict effectiveness and safety during opioid treatment for chronic low back pain: Results from a retrospective study in an Italian cohort. *Pharmacogenomics and Personalized Medicine*, *11*, 179–191.	The study aims to verify that CYP2D6 genetic polymorphisms can help to predict the effectiveness and safety of opioid-based drugs in clinical practice.	Cohort study (n=224)	CYP2D6 polymorphism was significantly associated with opioid treatment outcomes. CYP2D6 ultrarapid metabolizers showed an increase of side effects.	This article is from the medicine discipline. It confirms the role of CYP2D6 enzyme in pain management. Nurses may use this as scientific evidence in the knowledge translation process.
C) Hu et al. (2018). A Theoretical Framework for Interaction of Nursing Discipline with Genetics and Genomics. *International Journal of Nursing Sciences* 5(4):336–42.	The paper aims to synthesize and develop a theoretical framework for the interaction of nursing discipline with genetics and genomics.	Content analysis and comparative method.	The authors constructed a framework composed of four statements regarding: a) how genomics and genetics can influence nursing discipline, b) contribution of nursing discipline to genomics and genetics, c) a	The framework is developed by nurses. It illuminates the relationship between nursing disciplines and genomics, thus guiding how nurses can employ genomics in their practice. Written by nurses.

			paradigm shift as a result of the interaction, and d) implementation strategies to facilitate the interaction and the paradigm shift.	
D) White et al. (2019). Pharmacogenomics and psychiatric nursing. *Issues in mental health nursing*, 40(2), 194-198.	To investigate the impact of pharmacogenomic testing in management of mental health medication.	Retrospective chart review focused on 6 months pre-and post-pharmacogenomic testing (GeneSight Psychotropic)	100% of patients received augmentation of medications as results of pharmacogenomic testing. All patients reported less adverse side effects.	Pharmacogenomic testing may lead to changes in medication regimes with less side effects and more satisfaction in patients. Nurses may apply pharmacogenomics knowledge to counsel patients and advocate for their benefits. Written by nurses.
E) Moraes et al. (2020). Nurse empowerment through Pharmacogenetics. *Revista Latino-Americana de Enfermagem*, *28*.	The study aims to verify the existence of elements that justify the use of pharmacogegenetics by the Brazilian nurses.	Quantitative, cross-sectional, observational, descriptive study (n=67 patients)	The use of drugs metabolised by CYP2D9 was frequent. 19 adverse events associated with drugs metabolised by CYP2D9. There was a coincidence between the presence of low enzyme activity and the occurrence of adverse effects.	The authors argue for the significant role of nurses when appropriating pharmacogenetics as a tool for patient care: They administer drugs and empower patients by means of patient education. The nursing process can adopt pharmacogenomics, particularly where it involves pharmacogenomic testing. Written by nurses.
F) Prows (2011). Infusion of Pharmacogenetics Into Cancer Care. *Seminars in Oncology Nursing*, 27(1), 45–53.	To introduce nurses to how genetics-genomics is currently integrated into cancer care	Review of peer-reviewed literature and expert professional guidelines	Understanding genetic and genomic factors is important in cancer risk assessment, prevention, treatment, long-term management and surveillance Certain CYP2D6 variants inhibit metabolism of tamoxifen, a drug used in treatment of breast cancer.	Nurses can incorporate knowledge about pharmacogenomics when they administer medications, educate and counsell patients and their caretakers.
G) Kierce et al. (2019). Use of PHQ-9 and pharmacogenetic testing in clinical practice. *Journal of the American Association of Nurse Practitioners*, 31(9), 497-501.	To evaluate clinical use of pharmacogenetic testing in psychiatric practice, integrated measure for assessing depressive symptoms and captured data regarding	Pharmacogenetic testing on 15 adults baseline scores and recording of patients medication regimes	Results from pharmacogenetic testings led to removal of medications to patients who experienced significant drug-gene interactions.	Pharmacogenomic testing may be beneficial to new providers or when there is need for dose adjustment. However, decision to take the test should be considered in addition to patient preference, cost and immediate clinical needs.

	treatment efficacy			
H) Dodson (2014). Knowledge and attitudes of oncology nurses regarding pharmacogenomic testing. *Clinical Journal of Oncology Nursing,* 18(4), E64–E70.	To identify and test key elements that play a role in the adoption of pharmacogenomic testing into oncology practice	Cross-sectional, descriptive survey (n=368 nurses)	62% nurses felt that they sometimes use pharmacogenomic testing information. 53% trusted in pharmacogenomics. 80% observed decrease adverse drug events. 77% agreed that patients should be educated about pharmacogenomics. 89% perceived need of pharmacogenomics.	Nurses confirmed the need of integrating pharmacogenomics in their practice to improve patient outcomes.
I) Cheek et al. (2015). Pharmacogenomics and Implications for Nursing Practice. *Journal of Nursing Scholarship,* 47(6), 496–504.	To introduce pharmacogenomics and its implications for clinical nursing practice with regard to drug therapy	Review of peer-reviewed literature, websites, expert professional guidelines	Knowledge in pharmacogenomics is an essential nursing competency. The bedsides nurses monitor, advocate, educate (both patients and their family), obtain consent from patients for testing. All nurses need being capable of explaining to their patients about specific phenotypes CYP2D6, their risks for toxicity and poor responses to antidepressant therapy.	The authors argue that pharmacogenomics has significant implications on nursing practice: minimising side effects optimise patient outcomes. Nurses can make use of pharmacogenomics in their patient care through various manners: observation of side effects related to drugs, patient education, advocating for the use of pharmacogenomics in treatment plans.

3.2 Synthesis of the results

Pharmacogenomics in healthcare

Eight articles have examined the role of pharmacogenomics in healthcare (Aroke & Kittelsrud, 2020; Dagostino et al., 2018; Cheek et al., 2016; Dodson, 2014; Kierce et al., 2019; Moraes et al., 2018; Prows, 2011; White et al., 2018,). Among these, four articles have explored the importance of phenotyping CYP2D6 metabolising enzyme in three different healthcare settings: pain management, cancer care and mental health.

In pain management, Dagostino et al. (2018), Aroke and Kittelsrud (2020) point out evidence of the genetic differences that affect patient's responses to analgesic medications. In particular, CYP2D6 ultra rapid metabolisers showed an increased risks of side effects as would be predicted. Dagostino et al. (2018) find that CYP2D6

polymorphism is significantly associated with treatment outcomes for chronic lower back pain. Aroke and Kittelsrud (2020) present an algorithm (treatment guideline) which suggests that CYP2D6 poor metabolisers and ultra rapid metabolisers should avoid tramadol, codeine, oxycodone, and hydrocodone. Yet these patients may benefit from taking an alternative analgesic, namely fentanyl. Patients with CYP2D6 intermediate metaboliser and extensive metaboliser can be prescribed analgesics doses based on pain scores.

Integrating pharmacogenetics in cancer care is supported by Prows (2011). In her study, Prows presents that CYP2D6 enzyme is necessary for the biotransformation of tamoxifen (a standard adjuvant treatment for women with oestrogen receptor-positive breast cancer) to its most potent metabolite, endoxifen. Evidentially, clinical studies by Jin et al. and Kiyotani et al. (cited in Prows, 2011) reveal that women with a genotype associated with CYP2D6 poor metabolism phenotype have significantly lower mean plasma endoxifen concentrations. Prows also includes several studies that found a change in the individual CYP2D6 phenotype when patients use selective serotonin reuptake inhibitors (SSRIs) and tamoxin simultaneously over a long period. Therefore, Prows suggests that the nurse will need to assess if medications a patient is taking may alter the patient's genetic capacity to drug responses.

In mental care, nurses involved in the study by White et al. (2018) find a high incidence of CYP2D6 and CYP2C19 enzymes (which metabolise most psychotropic drugs) among patients diagnosed with psychiatric disorders. 82% of the sample carried different variations of CYP2D6, while 64% of individuals carried variations with CYP2C19.

The importance of phamacogenomic testing

The role of pharmacogenomic testing is mentioned in all included articles. They show that nurses are involved in pharmacogenomic testing in various manners.

Dodson (2014) reveals that nearly 50% of the nurses in the USA in her study (n=368 nurses) have cared for a patient who received a pharmacogenomic test. 23% study nurses have provided education about pharmacogenomic testing to their patients. 24% study nurses have advocated for a patient to undergo testing. 80% study nurses were positive about the association between the use of pharmacogenomics and a decrease in adverse drug events. Around 89% stated the need of pharmacogenomics in patient care.

On the same topic, Moreas et al. (2020) conducted a quantitative study to verify the existence of elements that justify the use of pharmacogenetics by the Brazilian nurses. Nurses conducted intravenous puncture to collect venous blood. DNA extraction was analysed to identify individual CYP2C9 genotype. Nurses also collected information about history of previous used medications metabolised by CYP2C9 enzyme and the occurrence of side effects. Their work found over 98% study participants used drugs that are metabolised by CYP2C9. 29% of the study population reported adverse reactions to medications.

Results from testing lead to adjustment in patients' pharmacotherapy. The testing resulted in augmentation of medication regime in 100% of the participants in the study by White et al. (2018). These patients also reported less adverse side effects and expressed satisfaction after switching medications. Pharmacogenetic testing also lead to changing in medication plan in a study by Kierce et al. (2019). These participants were

outpatients treated for depression disorder and were screened for genetic data. After testing, three out of these six participants had their medications eliminated after provider review. Three other participants were decided to continue with medications despite significant drug-gene interaction as provider argued that it would be in the best interest of these participants. Among them, a participant who had interaction reported as reduced efficacy" preferred not to change antidepressant despite the test results. The other two participants received a 20% decrease in their medication dose instead of discontinuing medication.

Furthermore, patients' interests in pharmacogenetic testing are also documented in the study by White et al. (2018). Patients asked specifically for genetic testing related to their response to medication. The study records no hesitance or concerns from the patients when genetic testings were taken and discussed.

Pharmacogenomics as nurses' new lens, technology, and competency

Hu et al. (2018) develop a theoretical framework for interaction of nursing discipline with genetics and genomics. Their framework comprises of four main theoretical statements. Two statements are relevant for this paper.

Firstly, nursing discipline can employ genetics and genomics in three ways: as a new specialty (advanced genetic nursing), new technologies (genetic and genomic technologies) and a new lens (using individual genetic profiles in the nursing process). Applications of pharmacogenomics by advanced nurses are also noted in the study by White et al. (2018). It took place in a psychiatric outpatient clinic in the USA. White et al. (2018) reveals that advanced nurses prescribed and reviewed 91% of pharmacogenomic testing. They also educated two thirds of the study patients. Eight out of 11 advanced nurses discussed the findings from testing with their patients. General nurses employing pharmacogenomics has been presented earlier in studies by Dodson (2014) and Moraes et al. (2020).

Secondly, nursing discipline can contribute back to genetics and genomics via its focus on how genes impact on individual drug responses and nurses' advocating for their clients in the genetic and genomic era (Hu et al., 2018).

Furthermore, Cheek et al. (2015) emphasise that pharmacogenomics knowledge is essential in nursing. They also provide clinical evidence that nurses can employ competencies in pharmacogenomics through being aware of different phenotypes or making use of information from genetic testing. Pharmacogenomics knowledge enhances nurses' ability to minimise side effects related to drugs and thereby ensuring optimal patient outcomes. Hu et al. (2018) present, for instance, that intensity of irritable syndromes (diarrhoea, bloating, colonic transit delay) and even patients' perceptions on illness are found to be associated with individual differences in genes.

4. Discussion

This paper examines how knowledge on pharmacogenomics may help nurses to improve patient outcomes. The following section addresses this question by firstly discussing how pharmacogenomics outlined from these articles provide important knowledge for nurses. Secondly, it discusses how nurses may translate this knowledge into the nursing practice to improve patient outcomes.

4.1 Knowledge on pharmacogenomics as scientific background for the nursing practice

Results from included articles show that genetic polymorphism presents greatly across patients. They may be the causes for side effects and ineffectiveness of medications to certain patients, particularly those who are low metabolisers or ultra rapid metabolisers. Moreover, individual genetic data can provide direction for nurses to personalize nursing interventions (Hu et al., 2018, p.339). Individualised care is also an important element in the nursing process according to Henderson (1995). Henderson explains that it means to see patient assignment rather than task assignment and this is one essence in nursing. Nursing is not only a helping act, but also a scientific act (Henderson, 1995, p.96-100). By including patients' genetic conditions, the nursing care can hence be said to be not only more individualised but also more scientific.

Firstly, pharmacogenomics can provide useful science for pain management. It guides appropriate analgesic dosage, thereby helping to reduce the number of adverse effects (Aroke & Kittelsrud, 2020). Reduced or absent CYP2D6 enzyme activity was found to be associated with therapeutic failure (Dagostino et al., 2018).
Their findings are confirmed by other studies on pharmacogenomics in pain management. For instance, Ting and Schug (2016, p.49) also state that genetics have been shown to be involved in almost every stage of pharmacokinetics and pharmacodynamics of analgesic agents. Particularly, CYP2D6 and CYP2C9 have major consequences for pain management. Kaye et al. (2020) reiterate that CYP2D6 polymorphisms and their metabolism of analgesics have undergone well-conducted clinical studies to provide evidence-based practice guidelines for analgesics prescription. In fact, the guidelines for codeine therapy in the context of CYP2D6 are working projects these days (Vuilleumier et al., 2019).

Consequently, this knowledge may be useful for postoperative nurses. Research has yielded concern for the need of improved knowledge on post-surgical analgesics (Dijk et al., 2017; Meissner et al., 2015). Poor pain management in the case of post-operative acute pain can lead to medical complications such as pneumonia, deep vein thrombosis, infection, chronic pain, and depression (Meissner et al., 2015). A study by Coluzzi et al. (cited in Meissner et al., 2015), for instance, shows that absence of adverse effects and adequate analgesia are the main determinants of satisfaction in patients who have undergone ambulatory hand surgery. Unless nurses increase their knowledge about pain management, patients will continue to experience moderate to severe pain post-surgery

despite recent advances in pain management (Mac Lellan, 2004). Medications will not benefit patients if they are not used correctly.

Secondly, knowledge on pharmacogenomics can be useful in mental care. A majority of antidepressant drugs are metabolised by CYP2D6 enzyme (Dagostino et al., 2018). The study by White et al. (2018) confirms that the application of pharmacogenomics in the realm of mental health has saved patients from the extensive period of trying new medications. This problem is often seen in mental care and referred as the "trial and error basis" (Foley & Quigley, 2010; White et al., 2018).

Thirdly, knowledge on pharmacogenomics can be useful in an oncology setting. Genetics testing is being used for a growing number of patients with different types of cancer (Becze, 2018; Dodson, 2017; Prows, 2011; Santos et al., 2013). In breast cancer care, genetic testing is conducted to predict a person's likely responses to medicines so that medication selection and dosing can be tailored to meet the individual needs and avoid adverse drug reactions (Prows, 2011).

In addition, guidelines on dosing for warfarin, clopidogrel, thiopurine based on pharmacogenetic testing are published by the Clinical Pharmacogenetics Implementation Consortium (Vuilleumier, 2019). White et al. (2018) express that nurses need "to maintain pace with science as it evolves". Nurses should embrace the exciting opportunities such as personalised medicine to improve patient outcomes and quality of life.

Nurse scientists (for example Cheek et al, 2015; Sink & Scardina, 2020) have implied that the implications of pharmacogenomics on nursing care are significant, and that knowledge in pharmacogenomics is important to all nurses. Understanding the genetic impacts on patient healthcare helps the nurse be more aware of the fact that pharmacogenomics can provide a more appropriate medication to patients who do not respond to standard treatment.

Moreover, there has been suggestion for a shift towards genotype-guided therapy in nursing (Aroke & Kittersrud, 2020; Hu et al., 2018). Individual genotype must be considered in addition to other lifestyles and environmental factors such as age, sex, smoking habit, diet, etc.

The inclusion of individual genetic data in nursing care ties well with Henderson's perspective (1997) on considering individual backgrounds in the nursing practice. I would argue that this individual difference lies also in individual genes. For example, different ethnic populations vary in incidence levels of the CYP2D6 enzyme phenotype (Aroke & Kittelsrud, 2020). Knowledge of varied genetic reactions among different populations can be very useful for nursing practice in Norway, given the increasing diversity of ethnics in the country.

4.2 Translating knowledge of pharmacogenomics into nursing practice

Knowledge translation aims to move knowledge from one field to another. In this case, it means that nurses may apply pharmacogenomics as scientific background in their nursing principle. Nurses can make efforts to narrow the disparity between "what nurses know" and "what nurses do" by employing pharmacogenomics into their practice.

Pharmacogenomics as empowerment of nurses

Today's nurses may empower themselves by taking advantage of advances in pharmacogenetics. Firstly, nurses can increase their competence by obtaining knowledge by way of education in pharmacogenomics (Dodson, 2014; Cheek, 2015; Moraes et al. 2020). A list of useful clinical online resources to assist nurses in familiarising and updating cancer genomic knowledge is presented in a paper by Santos et al. (2012, p.49). An improved knowledge in genomics is associated with an improved pharmacogenomic knowledge, and overall higher actual knowledge (Dodson, 2014, p.E68). Advances in genetics and genomics have added new technologies in healthcare (Hu et al., 2018). Therefore, nurses may make use of these technologies to enhance their practice.

Secondly, nurses can use pharmacogenomics as a new lens in the entire nursing process. This may imply a change in nurses' perspective on disease and subsequently their clinical practice (Hu et al., 2018). For instance, nurses can integrate genetic and genomics sciences on their first and other encounters with the patients by investigating family history of adverse events and allergy related to drugs, conducting pharmacogenetic testing, monitoring side effects related to medications and evaluating their effectiveness (Hu et al., 2018; Moraes et al., 2020; Prows 2011).

This way of adopting pharmacogenomics in nursing practice is consistent with Henderson's perspective (1995) on nursing in the technical age. By adopting a new technique, the nursing roles are taking on the new shift while making use of advances in genomics. Nurses may modify their nursing accordingly to patients' genetic makeup.

Furthermore, the fact that nurses learn and apply pharmacogenomics is in line with Henderson's concept of Habit of enquiry: As long as it serves patient-client's problem, nurses should practice the habit of enquiry throughout their life in nursing practice (Henderson, 1995, p.210). This also ties well to the idea of seeing knowledge translation as inquired-based practice presented by Doane and Varcoe (2008). Nurses actively enquire new perspectives and clues that seem relevant to the present nursing situations. Pharmacogenomics can be considered as one among these novel perspectives. Furthermore, this also reflects competence development, one among seven other important nursing functions (Kristoffersen, 2016, p.17). Kristoffersen (2016, p.170-172) comments that to practice nursing and to develop nursing competence are "two sides of the same coin".

Pharmacogenomics testing

Nurses may adopt knowledge about pharmacogenomic testing in their clinical practice. Several studies have emphasised the usefulness of screening of patients' CYP2D6 to identify individual genotype for better pain management (Aroke & Kittelsrud, 2020; Dagostino et al., 2018; Dodson, 2017; Moraes et al. 2020, Prows, 2011). Good diagnostics lead to good therapy and prevention, which improve quality of life of patients (Dagostino et al., 2018). If a pharmacogenetic test is prescribed by doctor, the nurse is likely to conduct the genetic tests in form of blood test or swab test.

Knowledge on pharmacogenetic testing can be applied in many forms. For instance, nurses can recognise which patients should be tested (Moraes et al., 2020). This consideration can be based on patient interview, observations of side effects and effectiveness related to prescribed medications. Nurses may also review the testing results to advocate and educate their patients. Studies have suggested that knowledgeable nurses can incorporate pharmacogenomic testing and genotype-guided therapy into routine practice to improve cancer care outcomes (Dodson, 2017; Santos et al. 2012).

Nurses making use of pharmacogenomic testing reflects Henderson's essence of nursing in the technological age. Today's nurses need to meet the increasing demand for technical skills to "get under the skin" of the patient-clients to discover which help the patient-clients need. Technical skills develop fast in number and complexity. Examples are drug administration and diagnostic tests (Henderson, 1995). The statement Hendenson made a few decades ago is even more relevant in the present era of pharmacogenomics. Furthermore, in line with Henderson's remark, it needs emphasising that the nurse conducts pharmacogenetic testing as ordinated by doctors and thereby functions as a member of the medical team. Nevertheless, knowledge in pharmacogenomic testing may also enable nurses to become the masters of their work.

Nonetheless, implementation of genomics and genetics may contain ethical dilemmas. As Hu et al. (2018) point out, genetic data contain sensitive information not only to an individual but also her/his family members. If results from genetic tests to patients show positive to a certain disease, it may imply that their family members are also at risk of having the same disease. The dilemma arises as nurses have to consider patient's autonomy, confidentiality versus non-maleficence to their family members. Hu et al. (2018, p.339-340) suggest that in certain cases, the duty to keep the patients' genetic information confidential is stronger than the rights of their family member to be informed that they are at risks. Other ethical considerations are mentioned in a study by Kierce et al. (2019) as they recruited participants for pharmacogenetic testing. These include the cost of testing, potential industry use of de-identified genetic data, uncertainty regarding future insurance discrimination and the possibility of emotional distress.

On another instance, Tuv et al. (2019) comment that the process of incorporating phamacogenetic testing into clinical practice advances more in the USA than in Europe. Applying pharmacogenomics in Norway faces a number of challenges. For examples, overall price for the total number of sequence variants (current price is NOK 146 per variant), difficulty to translate test results into clinical decisions, lack of equivalent Norwegian terminologies, and lack of standardisation of analytical repertoire, are among other factors. Yet, pharmacogenomics testing is being used in Norway aiming at better

clinical effects (as presented in studies by, for instance, Anstensrud et al., 2020, Romskaug et al., 2020).

I personally know history of a patient who did not respond as expected to the prescribed antidepressants. His symptoms worsened, which led to admission to psychiatric wards for following up. Here, he was screened for CYP2D6 phenotype. The test results showed that he was an ultra rapid metaboliser, which explained why the standard dose did not give expected effects. The nurse, who had been doubtful when the patient expressed his dissatisfaction with the medications, realised then it was of genetic cause and helped administer a new dose ordinated by the doctor.

Administrating, monitoring and evaluating pharmacotherapy

As pharmacogenomics can help improve patient outcomes, it can be said to help nurses fulfil their basic nursing as defined by Henderson. Today's nurses will need to employ genomic-genetic profiles of their patients prior the pharmacotherapy and bedside nurses must have knowledge on pharmacogenomics to minimalise adverse drug events (Cheek et al., 2015). Pharmacogenomic knowledge is not only useful for nurses who work in hospital settings, but also to all nurses who have medication responsibilities to their patients.

While taking part in pharmacotherapy, nurses observe the occurrence of side effects and whether improvement has taken place when a drug is administered. In pain management, CYP2D6 poor metabolisers may benefit no improvement of pain relief, and CYP2D6 ultra rapid metabolisers may experience an increase of side effects (Aroke & Kittelsrud, 2020; Dagostino, 2018). In another example, CYP2D6 poor metabolisers taking tricyclic antidepressants may experience side effects such as dry mouths, hypotension, sedation, tremor, or cardiotoxicity (Hu et al., 2018). Nurses use their clinical assessment and consider if it is necessary to report further to treating doctors. By this, nurses enable doctors to make timely therapy adjustments (Dilles et al., 2010).

Besides, awareness of gene-drug interaction can contribute to better understanding of patient behaviours. Aroke and Kittelsrud (2020) give an example that when a post-operative patient reports persistent pain despite escalating dose of codeine, this should be seen as an alert of the possibility of genetic predisposition and not merely drug-seeking behaviour. The same principle applies to tramadol. In my opinion, this is important knowledge that perioperative nurses should be aware of when administering and monitoring analgesics to post-operative patients. Back to my experience during internship at the pre- and post surgical ward, individual genetics might have helped explaining why some patients did not benefit from standard analgesic dose.

Advocating for patients

Nurses have a crucial role to advocate for patients (Hu et al., 2018; Moraes et al., 2010; White et al., 2018). This can be interpreted in two ways. Firstly, the nurse may need to explain to patients and their caretakers about the importance of having pharmacogenomics testing. Secondly, the nurse, on behalf of the patients and their

caretakers, may discuss with physicians about the need of testing to certain patients based on the nurse's assessment. In both ways, the aims are better treatment outcomes to the patient (fewer side effects, more drug efficacy). Hu et al. (2018) argue that nurses "must be anticipated and prepared to advocate for the rights of all individuals". The authors refer to adding genetics and genomics as a focus in nursing principle. This also ties well with the principle of beneficence, one of the four most important ethical principles in nursing. This principle requires nurses to actively take responsibilities and do their best for the sake of their patients (Nortvedt, 2016, p.96-97).

My experience from internships shows that many patients are dependent on nurses' clinical judgements and reports to physicians to get their doses adjusted. In the example I presented above about the patient with a psychiatric problem, had the nurses had knowledge about pharmacogenetics, the patient might have benefited from an adjusted dose sooner. However, it can be challenging for nurses to advocate for pharmacogenomics as it is a relatively recent phenomenon in nursing. White et al. (2018) also stress that this progress of integrating pharmacogenomics in nursing requires acceptance and understanding of pharmacogenomics by the nursing community. In my opinion, this can be done through raising awareness on pharmacogenomics among nurses and other healthcare professionals via research, seminars, setting up routines for genetic testing.

Educating and counselling patients/ caretakers

Patient education is an important function in the nursing practice (Kristoffersen, 2016). Knowledge on pharmacogenomics will allow nurses to provide guidance and education about the importance of pharmacogenomic testing to patients and their family (Dodson, 2014).

Studies have recorded, for example, that nurses inform patients about testing as a part of treatment plans (Dodson, 2014; Moraes et al., 2020; White et al., 2018). Nurses may take part in developing patient information regarding pharmacogenomics. For example, Moraes and her research team (2020) developed educational material to make the population aware of the use and importance of pharmacogenetics. They intended this would encourage patients to take the demands to the health care professionals so that pharmacogenetics can be used in a routine basis. Their work can be seen as empowering patients. From patients' perspective, study by White et al. (2018) records that patients asked for genetic testing specifically in relation to their response to medications. This shows that there may be increasing demands from acknowledgeable patients for more personalised care in the future.

In addition, Prows (2011) and White et al. (2018) emphasise that nurses need to teach patients to observe and report signs of medication allergy and side effects. Topics for patient education can also include food intakes, herbal products, or behaviours (such as smoking) that may interfere with drug absorption (Prows, 2011). For instance, grapefruit juice inhibits CYP3A4 enzyme and may lead to increased toxicity or reduce effects of drugs metabolised by this enzyme (Prows, 2011). Nurses may also need to help patients understand why pharmacogenetic testing may be necessary for their treatment plan (Dodson, 2014; White et al., 2018).

This is also in line with Henderson's perspective on continuation of care (Henderson, 1995, p.112). Henderson exemplifies that nurses support patients to own copies of their health records. This may enable patients and their family to understand and make use of these data in the future treatment. Henderson stresses that this will help preserve basic nursing care at least as much as the technological aspects.

Doing research in pharmacogenenomics

Translating pharmacogenomics into nursing practice can also take place through nurses conducting research. This also reflects the responsibility of the nursing profession to design its own method as highlighted by Henderson (1995, p.231). To my understanding, this means that the nurses take a heuristic approach to the theory of knowledge translation regarding pharmacogenomics. Doane et al. (2015) reconceptualise knowledge translation as an "action process" in which knowledge is socialised. The authors emphasise that nurses are positioned to lead and develop their clinical practice and care delivery systems in order to better support high-quality patient care and improve patient outcomes. This can be done through strong knowledge base, strategies to translate research findings into clinical practice, decision making, and healthcare policy.

Furthermore, Hu et al. (2018) suggest that nurses can do research on pharmacogenomics with a focus on nursing to contribute back to the field of pharmacogenomics. The authors also state that as genomics and nursing interact actively, a paradigm shift will occur. This paradigm is supposed to help nurses not only to employ genomics in the nursing profession but also to loosen the current theoretical stereotypes of the nursing discipline.

4.3 Strengths and limitations of this paper

On the one hand, I am aware that this paper contains certain limitations. Firstly, this paper has not covered all domains of the phenomenon of pharmacogenomics, which is progressing extensively. Secondly, this is a single-person work, which may have influenced on the screening and inclusion/exclusion of relevant articles. Thirdly, limitations are embedded in the included articles. For example, the study by Kierce et al. (2019) include a small sample size, the authors cannot confirm its generalisation to a larger population. The review by Cheek et al. (2015) selected literature based on the authors' expertise in field. Following Dalland's suggestions on source criticism (2017, p. 160), I used Web of Science to find out about the corresponding author Dennis Cheek and found that the author has in the last decades published several papers in the field of pharmacogenomics in nursing. The results presented in Moraes et al. (2020) do not appear to me to have directly addressed their research objective. The study was included because the authors gave solid discussion that justified their research objective.

On the other hand, eight out of nine original papers and reviews included are works done by nurses. I believe this increases the relevance and strengthens the argument that pharmacogenomics has implications for the nursing discipline. Six articles were published

within the last 5 years and three articles were published within last 10 years. This justifies the updated knowledge of pharmacogenomics presented in the paper. One study took place in Brazil and eight studies in the USA. This may imply a high degree of transferability to the Norwegian context.

4.4 Implications for nursing practice

According to Doane and Varcoe (2008), success in knowledge translation can be measured in the pragmatic outcomes of the nursing actions in responding to people's health and healing experiences. I contend that by taking the practical actions that are discussed in this section, nurses take their nursing care to a higher level, hence better patient outcomes.

There is also need for more clinical research conducted by nurses with the focus on pharmacogenomics in the nursing principle.

4.5 Conclusion

The ongoing genomic era has offered nurses opportunities to better the nursing practice. This paper set out to examine how knowledge on pharmacogenomics may help nurses to improve patient outcomes. Henderson's perspectives on nursing and theory of knowledge translation provide the paper's theoretical frameworks. A literature review was conducted and resulted in nine scientific studies comprised of original research and reviews. All articles were peer-reviewed and critically appraised.

Results from included studies show evidence of pharmacogenomics in various healthcare settings as important knowledge to minimise side effects and optimise efficacy of pharmacotherapy. Today's nurses can employ pharmacogenomics as new lens, technology, and competency in the nursing process. Information from pharmacogenomics testing have been used by nurses aiming at better clinical effects.

This paper has argued that knowledge on pharmacogenomics may help nurses in various ways. It adds more scienctific background to the nursing practice. It may empower nurses. It can be employed when nurses administer, monitor, and evaluate side effects and efficacy of the medication treatment. Furthermore, nurses can advocate for rights of their patients to benefit better outcomes from pharmacogenomics. Nurses may also educate pharmacogenomics to patients and their caretakers to take better care of themselves. Last, but not least, nurses can conduct research in pharmacogenomics as an approach to lead and develop their clinical practice, thereby improving quality of healthcare and patient outcomes.

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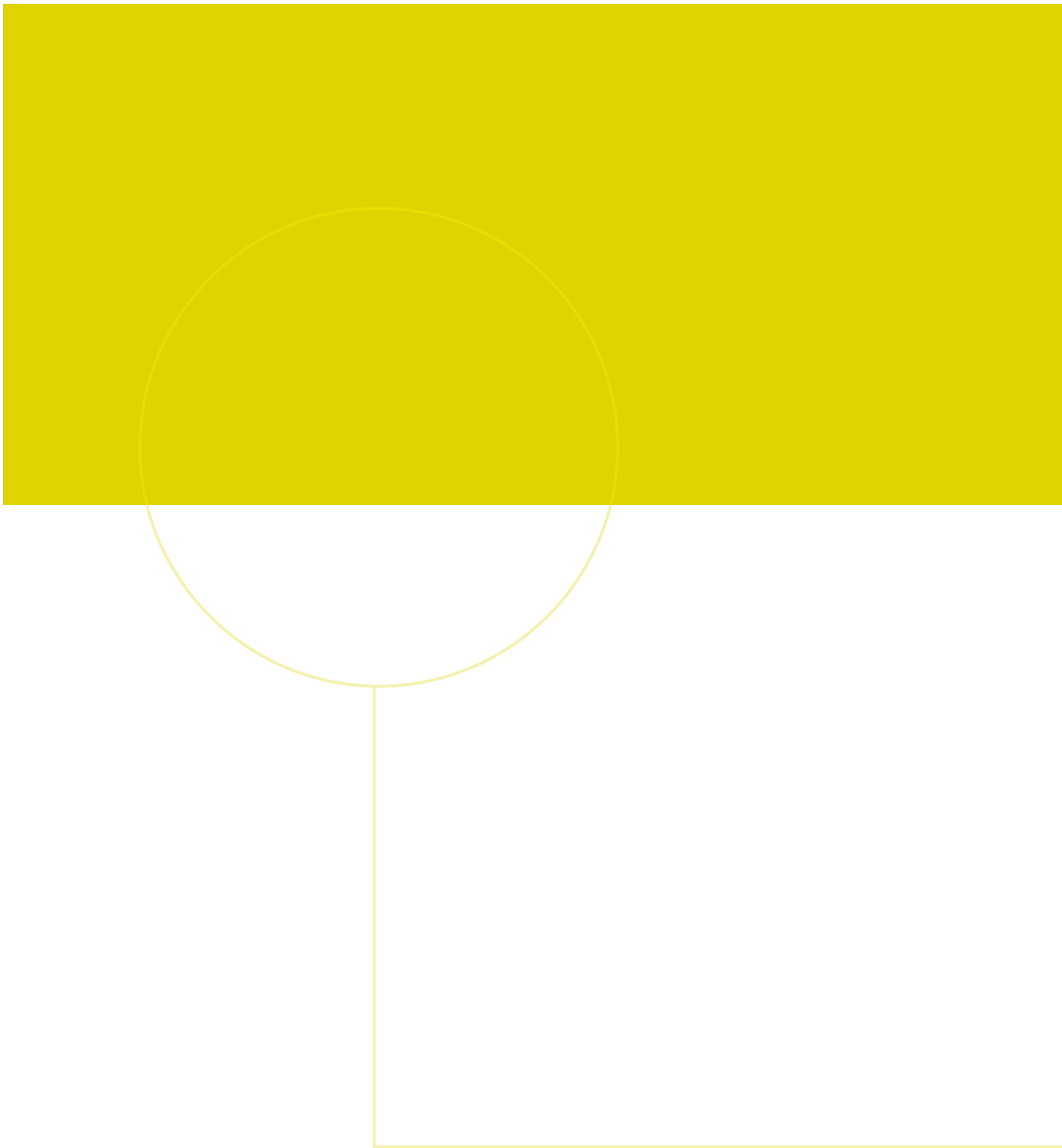

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