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Research and Applications

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Using drug knowledgebase information to distinguish between look-alike-sound-alike drugs

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ABSTRACT

Objective: To extract drug indications from a commercial drug knowledgebase and determine to what extent drug indications can discriminate between look-alike-sound-alike (LASA) drugs.

Methods: We extracted drug indications disease concepts from the MedKnowledge Indications module from First Databank Inc. (South San Francisco, CA) and associated them with drugs on the Institute for Safe Medication Practices (ISMP) list of commonly confused drug names. We used high-level concepts (rather than granular concepts) to represent the general indications for each drug. Two pharmacists reviewed each drug's association with its high-level indications concepts for accuracy and clinical relevance. We compared the high-level indications for each commonly confused drug pair and categorized each pair as having a complete overlap, partial overlap or no overlap in high-level indications.

Results: Of 278 LASA drug pairs, 165 (59%) had no overlap and 58 (21%) had partial overlap in high-level indications. Fifty-five pairs (20%) had complete overlap in high-level indications; nearly half of these were comprised of drugs with the same active ingredient and route of administration (e.g., *Adderall*, *Adderall XR*).

Conclusions: Drug indications data from a drug knowledgebase can discriminate between many LASA drugs.

Key words: indications, look-alike-sound-alike, LASA, medication safety

INTRODUCTION

Confusion involving look-alike, sound-alike (LASA) drug names is a known source of preventable medication error that can lead to adverse events, serious patient harm, and substantial healthcare costs.[1–4] Various patient safety organizations, accrediting bodies, and regulatory agencies have advocated for strategies to identify and manage risks associated with LASA drugs.[5–7] Examples include the use of bar code technology, Tall Man (mixed case) lettering, separate storage of LASA drugs, inclusion of both brand and generic medication names on orders and labels, specifying the purpose of the drug when it is prescribed, and checking that a patient's active diagnosis matches the indication of a drug prior to dispensing or administering the drug.[5–7] Regulatory agencies, including the Joint Commission, are encouraging organizations to proactively identify LASA pairs and take action to prevent medication errors with LASA drugs.[8] The U.S. Food and Drug Administration (FDA) and Health Canada have also issued guides to identify potentially confusing drug names during the premarket phase of drug development.[9–11] The expanding use of electronic health records has the potential to reduce LASA errors due to improved legibility and more efficient

and accurate transmission of prescriptions. However, computerized systems can also introduce LASA errors. Pick-lists where LASA drugs appear next to each other and variation in the format of drug name displays on order screens, for example, can increase the risk of drug selection errors.[12,13]

As part of a larger project that advocates for incorporating indications in the prescription ordering phase, we conducted a study to determine whether drug indications knowledgebase content could be used to distinguish between LASA drugs.[14] We used the MedKnowledge Indications module from First Databank, Inc. (South San Francisco, CA) as the source of drug indications data, and the nine-page listing of confused drug names maintained by the Institute for Safe Medication Practices (ISMP) as our source for LASA drugs.[15,16] The purpose of this project was to determine whether drug indications could potentially be used to discriminate between LASA drug names.

METHODS

Data Sources

ISMP's list of confused drug names is a compilation of generic and brand drug name pairs reported to ISMP as having caused drug errors due to name confusion.[16] Since the drug name pairs are a cumulative collection of drug name pairs over time, we used the drugs@fda database and FDA National Drug Code directory to identify and exclude drugs that were no longer marketed in the U.S. or branded products that had undergone a brand name change.[17,18]

We used the Indications module from First Databank as the source of drug indications.[15] The Indications module is a proprietary knowledgebase that includes FDA-approved and "off-label" indications for prescription and non-prescription drugs and is used in many applications within health care, including clinical decision support. Module content is specific to the active ingredient, dose form, strength and route of administration for a given drug. Reference sources used to compile and update indications data include the manufacturer product labeling, medical reference texts, treatment guidelines, expert consensus statements and primary medical literature. FDA-approved indications may also be removed from a drug in the module if the drug is no longer the standard of care for the indication, e.g., penicillin G for treatment of Neisseria gonorrhea infection. The Indications module excludes most dietary supplements, herbal products, large volume parenteral products, diluents, veterinary drugs, medical supplies, medical devices, and bulk drug substances used in compounding.

The Indications module is used in conjunction with a proprietary concept-based medical vocabulary called the First Databank Medical Lexicon (FML).[19] FML is comprised of disease concept codes and descriptions that represent medical diagnoses, disease states, and health-related conditions or procedures. Examples of disease concept descriptions include "mania associated with bipolar disorder" or "loss of bone mineral density due to aromatase inhibitor therapy." Disease concept descriptions can be searched or displayed using either professional terminology (e.g., post herpetic neuralgia), medical abbreviations (e.g., PHN) or consumer-friendly terms (e.g., nerve pain after herpes). FML disease concepts are also mapped to interoperable terminologies (e.g., ICD, SNOMED) to allow for related concept searching.

We had considered using ICD or SNOMED terms to represent drug indications but found that the standardized code sets did not adequately address certain concepts such as disease prevention (e.g., prevention of gastrointestinal ulcer), diagnostic testing for disease, or treatment of symptoms related to disease (e.g., anemia due to bleeding uterine leiomyoma). We chose to use the FML medical vocabulary because we had access to the content, and it offered a more precise representation of drug indications than what we could find in the standardized terminologies.

Because disease concept descriptions exist at varying levels of granularity for different drugs, and drugs may be associated with many disease concepts, we used two data elements in the Indications module – the disease concept proxy and the disease concept grouping – to identify the broad indication(s) for a given drug.

The disease concept proxy represents a single general indication for a drug that is used to facilitate drug-disease interactions checking. For example, many antibiotics are assigned a proxy of "bacterial infection" that can be utilized as an inferred patient problem when screening a new prescription for drug-disease interactions. Similarly, antifungal and antiviral agents are assigned a proxy of "fungal infection" and "viral infection," respectively. In addition, most antineoplastic drugs are assigned a proxy of "malignancy." For this study, we used the disease concept proxy to represent the high-level indication for anti-infective (antibacterial, antiviral, and antifungal) agents and antineoplastic drugs. For all other drugs, we used the disease concept grouping.

The disease concept grouping is a high-level disease concept (i.e., roll-up term) assigned to each drug-disease concept pair that can be used to shorten long tabular displays of granular indications lists. For example, insulin is associated with the granular disease concepts "gestational diabetes mellitus," "type 1 diabetes mellitus" and "type 2 diabetes mellitus," and each of these concepts is associated with the disease concept grouping "diabetes mellitus." Similarly, for the drug risedronate, the granular disease concepts "post-menopausal osteoporosis" and "glucocorticoid-induced osteoporosis" are associated with the disease concept grouping "osteoporosis" (Figure 1). A given drug may be associated with one or more disease concept groupings in the Indications module.

We presumed that using high-level concepts would be a conservative and more practical approach to evaluating overlaps in indications between drugs that were paired on the ISMP list.

Data Synthesis

In June 2017, one pharmacist (CC) extracted the high-level indications from the Indications module (either disease concept proxy or disease concept grouping) for each drug on the ISMP list. If only the active ingredient was listed on the ISMP list, then we extracted the high-level indications for every dose form, strength and route of administration available for the product. For example, cyclosporine is associated with distinct indications for its oral, intravenous, and ophthalmic formulations. Each drug-indication set was then compared to its corresponding confused drug-indication set. Two pharmacists (AS, MGA) reviewed the data for accuracy and clinical relevance. Any issues were resolved by consensus through discussion.

We recorded all instances where the drug and confused drug had the same high-level indication (i.e., indication overlap). We then categorized the degree of indication overlap within each drug pair. A "complete overlap" was defined as an instance where all high-level indications for a drug and its corresponding confused drug were the same. A "partial overlap" was defined as an instance where some of the high-level indications for a drug and its corresponding confused drug were the same. A "no overlap" was defined as an instance

Drug	Disease Concept Grouping	Disease Concept
risedronate	osteoporosis	post-menopausal osteoporosis
		osteoporosis in male patient
		glucocorticoid-induced osteoporosis
	osteoporosis prevention	post-menopausal osteoporosis prevention
		prevention of glucocorticoid-induced osteoporosis
	Paget's disease of bone	Paget's disease of bone

Figure 1. Example of disease concept and disease concept groupings for oral risedronate.

where none of the high-level indications for a drug and its corresponding confused drug were the same. All data were recorded on a Microsoft Excel (2016) worksheet.

Analysis

We used descriptive statistics to describe the number and proportion of drug pairs with complete, partial, and no overlap in high-level indications. For drug pairs with a partial overlap, we used the Dice Similarity Coefficient (DSC) to compare the similarity in indications between drugs within a pair.[20] The DSC has been used to evaluate lexical similarity between text strings.[21] We used DSC to measure the extent of overlap between indications within a drug pair. The DSC was calculated as follows:

DSC = (2 * number of shared indications between drug A and drug B)/(number of indications for drug A + number of indications for drug B), where drug A is one drug within a drug pair, and drug B is the corresponding confused drug of the pair.

The DSC value ranges from 0 (no overlap in high-level indications) to 1 (complete overlap in high-level indications). A DSC value between 0 and 1 can be interpreted as the probability that an overlap in high-level indications will occur within a given pair of drugs.

RESULTS

There were 399 unique LASA drug pairs comprised of 646 unique drugs. A total of 123 drugs were excluded because they had been discontinued in the US (n = 89), were non-US products (n = 6), had had a name change (n = 4), represented a drug class instead of an individual drug (n = 2) or were out-of-scope for the Indications module (n = 22). The four drugs that had undergone a name change were *Altocor* (changed to *Altoprev* in 2004), *Reminyl* (changed to *Razadyne* in 2005), *Kapidex* (changed to *Dexilant* in 2010), and *Brintellix* (changed to *Trintellix* in 2016).[18] The two names that represented a drug class instead of an individual drug were HMG Co-A reductase inhibitors ("statins") and proton pump inhibitors. Drugs that were out-of-scope for the Indications module included dietary supplements (e.g., *Floranex*, *Florastor*, *Glycotrol*), medical devices (e.g., *Healon* and *Arista AH*), bulk fluids (e.g., acetic acid for irrigation), and antiseptic agents (e.g., *Cidex*, *Betadine*). A total of 121 drug pairs were excluded because one or both drugs within the pair met exclusion criteria.

The 278 included drug pairs were comprised of 452 unique drugs that were each associated with an average of 2.4 high-level indications (range 1 to 11). There were 197 drugs with a single high-level indication. There were 181 generic names and 271 brand names in our study sample.

There were 165 (59%) pairs with no overlap in high-level indications. There was an average of 5 distinct high-level indications within each drug pair (range 2 to 14) (Table 1).

There were 58 drug pairs (21%) with a partial overlap of high-level indications. Each pair had an average of 5 distinct high-level indications (range 2 to 14). The mean DSC was 0.53 (range 0.17 to 0.93) (Table 2).

There were 55 drug pairs (20%) with complete overlap in high-level indications. Each of these pairs shared a single, common high-level indication (Table 3). Most comparisons were between antineoplastic drugs (n = 13, 24%), anti-infective agents (n = 10, 18%), antidiabetic drugs (n = 9, 16%), or opioid analgesics (n = 5, 9%). Nearly half of the drug pairs (n = 24, 44%) were comprised of drugs with the same active ingredient and route of administration.

DISCUSSION

This study shows that nearly 60% of the ISMP confused drug pairs included in our dataset had no overlap in indications, and another 21% of the drug pairs had just a partial overlap in indications. Associating indications with these drugs may help to differentiate these pairs and eliminate confusion between them. The remaining 20% of the drug pairs contained drugs with the same high-level indication. Many of these drug pairs were comprised of drugs with the same active ingredient and route of administration and differed only in dosage form (e.g., *Seroquel* vs *Seroquel XR*), strength (e.g., *Ortho Tri-Cyclen* vs *Ortho Tri-Cyclen LO*) or formulation (e.g., paclitaxel

Table 1. ISMP confused drug name pairs with *no overlap* in high-level indications*

Drug A				Drug B				Number of high-level indications within pair*
Name†	Name type	Active ingredient(s)	Route(s)	Name†	Name type	Active ingredient(s)	Route(s)	
Aggrastat	brand	tirofiban	IV	argatroban	generic	argatroban	IV	2
Anzemet	brand	dolasetron	oral, IV	Avandamet	brand	rosiglitazone / metformin	oral	2
BabyBIG	brand	botulism immune globulin	IV	HBIG (hepatitis B immune globulin)	brand	hepatitis b immune globulin	IM	2
Bidex	brand	guaifenesin	oral	Videx	brand	didanosine	oral	2
DACTINomycin	generic	dactinomycin	IV	DAPTOmycin	generic	daptomycin	IV	2
Denavir	brand	penciclovir	topical	indinavir	generic	indinavir	oral	2
Farxiga	brand	dapagliflozin	oral	Fetzima	brand	levomilnacipran	oral	2
flumazenil	generic	flumazenil	IV	influenza virus vaccine	generic	influenza virus vaccine	IM	2
influenza virus vaccine	generic	influenza virus vaccine	IM	perflutren lipid microspheres	generic	perflutren lipid microspheres	IV	2
influenza virus vaccine	generic	influenza virus vaccine	IM	tuberculin purified protein derivative (PPD)	generic	tuberculin, purified protein derivative	intradermal	2
Keflex	brand	cephalexin	oral	Keppra	brand	levetiracetam	oral, IV	2
methylene blue	generic	methylene blue	IV	VisionBlue	brand	trypan blue	intraocular	2
nalbuphine	generic	nalbuphine	SC, IM, IV	naloxone	generic	naloxone	injection, nasal	2
Oracea	brand	doxycycline	oral	Orencia	brand	abatacept	SC	2
Patanol	brand	olopatadine	ophthalmic	Platinol	brand	cisplatin	IV	2
sitaGLIPtin	generic	sitagliptin	oral	SUMAtriptan	generic	sumatriptan	SC, oral, nasal	2
tetanus diptheria toxoid (Td)	generic	tetanus and diphtheria toxoids, adult	IM	tuberculin purified protein derivative (PPD)	generic	tuberculin, purified protein derivative	intradermal	2
tiaGABine	generic	tiagabine	oral	tiZANidine	generic	tizanidine	oral	2
traMADol	generic	tramadol	oral	traZODone	generic	trazodone	oral	2
Vexol	brand	rimexolone	ophthalmic	Vosol	brand	acetic acid	otic	2
Xeloda	brand	capecitabine	oral	Xenical	brand	orlistat	oral	2
Antivert	brand	meclizine	oral	Axert	brand	almotriptan	oral	3
Apidra	brand	insulin glulisine	SC	Spiriva	brand	tiotropium	inhalation	3
Aricept	brand	donepezil	oral	Azilect	brand	rasagiline	oral	3
Avandia	brand	rosiglitazone	oral	Coumadin	brand	warfarin	oral	3
Clindesse	brand	clindamycin	vaginal	Clindets	brand	clindamycin	topical	3
dexmethylphenidate	generic	dexmethylphenidate	oral	methadone	generic	methadone	oral, injection	3
Diflucan	brand	fluconazole	oral, IV	Diprivan	brand	propofol	IV	3
Diprivan	brand	propofol	IV	Ditropan	brand	oxybutynin	oral	3
DOBUTamine	generic	dobutamine	IV	DOPamine	generic	dopamine	IV	3
Doribax	brand	doripenem	IV	Zovirax	brand	acyclovir	oral, topical	3
edetate calcium disodium	generic	edetate calcium disodium	injection	edetate disodium	generic	edetate disodium	IV	3
Enjuvia	brand	estrogens, conjugated, synthetic b	oral	Januvia	brand	sitagliptin	oral	3
Fanapt	brand	iloperidone	oral	Xanax	brand	alprazolam	oral	3
gentamicin	generic	gentamicin	injection, ophthalmic, topical	gentian violet	generic	gentian violet	topical	3
guaiFENesin	generic	guaifenesin	oral	guanFACINE	generic	guanfacine	oral	3
Jantoven	brand	warfarin	oral	Janumet	brand	sitagliptin /metformin	oral	3
Jantoven	brand	warfarin	oral	Januvia	brand	sitagliptin	oral	3
Janumet	brand	sitagliptin/ metformin	oral	Sinemet	brand	carbidopa/levodopa	oral	3
Kaletra	brand	lopinavir/ritonavir	oral	Keppra	brand	levetiracetam	oral, IV	3
LaMICtal	brand	lamotrigine	oral	LamISIL	brand	terbinafine	topical, oral	3
Lanoxin	brand	digoxin	oral, injection	naloxone	generic	naloxone	injection, nasal	3

(continued)

Table 1. continued

Drug A				Drug B				Number of high-level indications within pair*
Name†	Name type	Active ingredient(s)	Route(s)	Name†	Name type	Active ingredient(s)	Route(s)	
lanthanum carbonate	generic	lanthanum carbonate	oral	lithium carbonate	generic	lithium carbonate	oral	3
Lantus	brand	insulin glargine	SC	Latuda	brand	lurasidone	oral	3
levETIRAcetam	generic	levetiracetam	oral, IV	levofloxacin	generic	levofloxacin	oral, IV, ophthalmic	3
lithium	generic	lithium	oral	Ultram	brand	tramadol	oral	3
Lunesta	brand	eszopiclone	oral	Neulasta	brand	pegfilgrastim	SC	3
Matulane	brand	procarbazine	oral	Materna	brand	prenatal vitamins with calcium/ferrous fumarate/folic acid	oral	3
methadone	generic	methadone	oral, injection	methylphenidate	generic	methylphenidate	oral	3
methimazole	generic	methimazole	oral	metolazone	generic	metolazone	oral	3
Mucinex	brand	guaifenesin	oral	Mucinex Allergy	brand	fexofenadine	oral	3
Neulasta	brand	pegfilgrastim	SC	Neumega	brand	oprelvekin	SC	3
Neulasta	brand	pegfilgrastim	SC	Nuedexta	brand	dextromethorphan / quinidine	oral	3
Prenexa	brand	prenatal vitamin,-calcium/iron/folic acid/docusate/docosahexaenoic acid	oral	Ranexa	brand	ranolazine	oral	3
Razadyne	brand	galantamine	oral	Rozerem	brand	ramelteon	oral	3
Salagen	brand	pilocarpine	oral	selegiline	generic	selegiline	oral, transdermal	3
sotalol	generic	sotalol	oral, IV	Sudafed	brand	pseudoephedrine	oral	3
sulfADIAZINE	generic	sulfadiazine	oral	sulfaSALAzine	generic	sulfasalazine	oral	3
Tenex	brand	guanfacine	oral	Xanax	brand	alprazolam	oral	3
Tracleer	brand	bosentan	oral	Tricor	brand	fenofibrate,micronized	oral	3
zolpidem	generic	zolpidem	oral, sublingual	Zyloprim	brand	allopurinol	oral	3
Zostrix	brand	capsaicin	topical	Zovirax	brand	acyclovir	oral, topical	3
Zovirax	brand	acyclovir	oral, topical	Zyvox	brand	linezolid	oral, IV	3
Metadate	brand	methylphenidate	oral	methadone	generic	methadone	oral, injection	3
Actonel	brand	risedronate	oral	Actos	brand	pioglitazone	oral	4
atomoxetine	generic	atomoxetine	oral	atorvastatin	generic	atorvastatin	oral	4
Brevibloc	brand	esmolol	IV	Brevital	brand	methohexital	injection	4
Clozaril	brand	clozapine	oral	Colazal	brand	balsalazide	oral	4
Colace	brand	docusate	oral, rectal	Cozaar	brand	losartan	oral	4
Foradil	brand	formoterol	inhalation	Fortical	brand	calcitonin,salmon	nasal	4
Levemir	brand	insulin detemir	SC	Lovenox	brand	enoxaparin	SC	4
metFORMIN	generic	metformin	oral	metroNIDAZOLE	generic	metronidazole	oral, topical, vaginal, IV	4
Miralax	brand	polyethylene glycol 3350	oral	Mirapex	brand	pramipexole	oral	4
Neumega	brand	oprelvekin	SC	Neupogen	brand	filgrastim	injection	4
penicillamine	generic	penicillamine	oral	penicillin	generic	penicillin v potassium; penicillin g sodium; penicillin g procaine	oral, injection	4
Sonata	brand	zaleplon	oral	Soriatane	brand	acitretin	oral	4
Tiazac	brand	diltiazem	oral	Ziac	brand	bisoprolol /hydrochlorothiazide	oral	4
Allegra	brand	fexofenadine	oral	Viagra	brand	sildenafil	oral	4
Allegra (fexofenadine)	brand	fexofenadine	oral	Allegra Anti-Itch (diphenhydrAMINE/ allantoin)	brand	diphenhydramine/ allantoin	topical	4

(continued)

Table 1. continued

Drug A				Drug B				Number of high-level indications within pair*
Name†	Name type	Active ingredient(s)	Route(s)	Name†	Name type	Active ingredient(s)	Route(s)	
amantadine	generic	amantadine	oral	amiodarone	generic	amiodarone	oral, IV	5
Amicar	brand	aminocaproic acid	oral, IV	Omacor	brand	omega-3 acid ethyl esters	oral	4
Asacol	brand	mesalamine	oral	Os-Cal	brand	calcium carbonate	oral	5
azaCITIDine	generic	azacitidine	injection	azaTHIOprine	generic	azathioprine	oral, injection	5
buPROPion	generic	bupropion	oral	busPIRone	generic	buspirone	oral	5
Femara	brand	letrozole	oral	Femhrt	brand	norethindrone/ethinyl estradiol	oral	4
Flonase	brand	fluticasone propionate	nasal	Flovent	brand	fluticasone	inhalation	4
Inspra	brand	eplerenone	oral	Spiriva	brand	tiotropium	inhalation	4
lamoTRIgine	generic	lamotrigine	oral	levothyroxine	generic	levothyroxine	oral, IV	4
Lanoxin	brand	digoxin	oral, injection	levothyroxine	generic	levothyroxine	oral, IV	4
Mephyton	brand	phytonadione (vit k1)	oral	methadone	generic	methadone	oral, injection	4
Metadate ER	brand	methylphenidate	oral	methadone	generic	methadone	oral, injection	4
methadone	generic	methadone	oral, injection	metolazone	generic	metolazone	oral	4
oxaprozin	generic	oxaprozin	oral	OXcarbazepine	generic	oxcarbazepine	oral	4
Rapaflo	brand	silodosin	oral	Rapamune	brand	sirolimus	oral	4
Reprexain	brand	hydrocodone/ibuprofen	oral	ZyPREXA	brand	olanzapine	oral, IM	5
rifampin	generic	rifampin	oral, IV	rifaximin	generic	rifaximin	oral	5
silodosin	generic	silodosin	oral	sirolimus	generic	sirolimus	oral	4
Zelapar (Zydis formulation)	brand	selegiline	oral	ZyPREXA Zydis	brand	olanzapine	oral	5
desipramine	generic	desipramine	oral	disopyramide	generic	disopyramide	oral	6
Effexor XR	brand	venlafaxine	oral	Enablex	brand	darifenacin	oral	6
flavoxATE	generic	flavoxate	oral	fluvoxaMINE	generic	fluvoxamine	oral	6
Intuniv	brand	guanfacine	oral	Invega	brand	paliperidone	oral	6
NexAVAR	brand	sorafenib	oral	NexIUM	brand	esomeprazole	oral, IV	6
Restoril	brand	temazepam	oral	RisperDAL	brand	risperidone	oral	6
Zestril	brand	lisinopril	oral	Zetia	brand	ezetimibe	oral	6
Cardura	brand	doxazosin	oral	Coumadin	brand	warfarin	oral	5
colchicine	generic	colchicine	oral	Cortrosyn	brand	cosyntropin	injection	5
Doxil	brand	doxorubicin pegylated liposomal	IV	Paxil	brand	paroxetine	oral	7
leucovorin calcium	generic	leucovorin calcium	oral, injection	Leukeran	brand	chlorambucil	oral	5
Lotronex	brand	alosetron	oral	Protonix	brand	pantoprazole	oral, IV	7
NIFEdipine	generic	nifedipine	oral	niMODipine	generic	nimodipine	oral	5
Paxil	brand	paroxetine	oral	Taxol	brand	paclitaxel	IV	7
Proscar	brand	finasteride	oral	Provera	brand	medroxyprogesterone	oral	5
protamine	generic	protamine	IV	Protonix	brand	pantoprazole	oral	7
Zerit	brand	stavudine	oral	ZyrTEC	brand	cetirizine	oral	5
cycloSERINE	generic	cycloserine	oral	cycloSPORINE	generic	cyclosporine	oral, IV, ophthalmic	8
Thalomid	brand	thalidomide	oral	Thiamine	brand	thiamine	oral, injection	8
Advair	brand	fluticasone /salmeterol	inhalation	Advicor	brand	niacin/lovastatin	oral	6
CeleBREX	brand	celecoxib	oral	Cerebyx	brand	fosphenytoin	injection	6
cetirizine	generic	cetirizine	oral	stavudine	generic	stavudine	oral	6
clomiPHENE	generic	clomiphene	oral	clomiPRAMINE	generic	clomipramine	oral	6
Diovan	brand	valsartan	oral	Zyban	brand	bupropion	oral	6
Enbrel	brand	etanercept	SC	Levbid	brand	hyoscyamine	oral	6
heparin	generic	heparin	injection	Hespan	brand	hetastarch in 0.9% sodium chloride	IV	6
lamiVUDine	generic	lamivudine	oral	lamoTRIgine	generic	lamotrigine	oral	6

(continued)

Table 1. continued

Drug A				Drug B				Number of high-level indications within pair*
Name†	Name type	Active ingredient(s)	Route(s)	Name†	Name type	Active ingredient(s)	Route(s)	
Prograf	brand	tacrolimus	oral, IV	PROzac	brand	fluoxetine	oral	9
Pyridium	brand	phenazopyridine	oral	pyridoxine	generic	pyridoxine	oral, injection	6
Aldara	brand	imiquimod	topical	Alora	brand	estradiol	transdermal	6
antacid	generic	magnesium /aluminum/sodium bicarbonate	oral	Atacand	brand	candesartan	oral	6
Cozaar	brand	losartan	oral	Zocor	brand	simvastatin	oral	6
Zocor	brand	simvastatin	oral	ZyrTEC	brand	cetirizine	oral	6
Aciphex	brand	rabeprazole	oral	Aricept	brand	donepezil	oral	7
fomepizole	generic	fomepizole	IV	omeprazole	generic	omeprazole	oral	7
Lasix	brand	furosemide	oral, injection	Luvox	brand	fluvoxamine	oral	7
risperiDONE	generic	risperidone	oral	rOPINIRole	generic	ropinirole	oral	7
Xanax	brand	alprazolam	oral	Zantac	brand	ranitidine	oral, injection	7
CeleXA	brand	citalopram	oral	Cerebyx	brand	fosphenytoin	injection	8
hydrALAZINE	generic	hydralazine	oral, injection	hydrOXYzine	generic	hydroxyzine	oral, IM	8
Lexiva	brand	fosamprenavir	oral	Pexeva	brand	paroxetine	oral	8
Lipitor	brand	atorvastatin	oral	ZyrTEC	brand	cetirizine	oral	7
PARoxetine	generic	paroxetine	oral	piroxicam	generic	piroxicam	oral	7
chlordiazePOXIDE	generic	chlordiazepoxide	oral	chlorproMAZINE	generic	chlorpromazine	oral, injection	9
chlorproMAZINE	generic	chlorpromazine	oral, injection	chlorproPAMIDE	generic	chlorpropamide	oral	9
Hydrea	brand	hydroxyurea	oral	Lyrica	brand	pregabalin	oral	9
Accupril	brand	quinapril	oral	Aciphex	brand	rabeprazole	oral	8
PriLOSEC	brand	omeprazole	oral	Pristiq	brand	desvenlafaxine	oral	11
Zantac	brand	ranitidine	oral, injection	ZyrTEC	brand	cetirizine	oral	8
Zegerid	brand	omeprazole/sodium bicarbonate	oral	Zestril	brand	lisinopril	oral	8
Diabinese	brand	chlorpropamide	oral	Diamox	brand	acetazolamide	oral	10
ZyPREXA	brand	olanzapine	oral, IM	ZyrTEC	brand	cetirizine	oral	8
Paxil	brand	paroxetine	oral	Plavix	brand	clopidogrel	oral	9
sertraline	generic	sertraline	oral	Soriatane	brand	acitretin	oral	9
Adderall	brand	dextroamphetamine /amphetamine	oral	Inderal	brand	propranolol	oral	12
Zestril	brand	lisinopril	oral	ZyPREXA	brand	olanzapine	oral, IM	9
cyclophosphamide	generic	cyclophosphamide	oral, IV	cycloSPORINE	generic	cyclosporine	oral, IV, ophthalmic	10
LORazepam	generic	lorazepam	oral, injection	Lovaza	brand	omega-3 acid ethyl esters	oral	17
CeleBREX	brand	celecoxib	oral	CeleXA	brand	citalopram	oral	10
cetirizine	generic	cetirizine	oral	sertraline	generic	sertraline	oral	14
ARIPiprazole	generic	aripiprazole	oral, IM	RABEprazole	generic	rabeprazole	oral	10
Benadryl	brand	diphenhydramine	topical, oral, injection	benazepril	generic	benazepril	oral	11
clonazePAM	generic	clonazepam	oral	cloNIDine	generic	clonidine	oral, transdermal, epidural	13
cloNIDine	generic	clonidine	transdermal, oral, epidural	KlonoPIN	brand	clonazepam	oral	12
SandIMMUNE	brand	cyclosporine	oral, IV	SandoSTATIN	brand	octreotide	injection	12
PriLOSEC	brand	omeprazole	oral	PROzac	brand	fluoxetine	oral	13
Lopressor	brand	metoprolol tartrate	oral	Lyrica	brand	pregabalin	oral	14

*disease concept grouping or disease concept proxy

†Drug A and Drug B names are as represented on ISMP's list of confused drug names

IM = intramuscular, IV= intravenous, SC = subcutaneous

vs paclitaxel protein-bound). Our results are consistent with a recent study that used only FDA-approved indications to differentiate a smaller set (33 drug pairs) of LASA drug names.[22] To our knowledge, this is the first study to systematically evaluate the degree of overlapping indications (FDA approved and unapproved) between LASA drugs reported to ISMP.

For decades, leading authorities have recommended adding indications to medication orders to prevent errors and confusion between LASA drugs.[5,16] However, there is limited quantitative data on how many LASA drugs mix-ups could be prevented using indications. Our study shows that associating indications to LASA medications is a potentially powerful lever since more than half of these medication pairs could be distinguished even with high-level indications concepts.

Current strategies for avoiding LASA errors include use of bar code technology, storage of LASA drugs apart from each other, use of Tall Man lettering, adding extra security labels to the outer packaging of LASA drugs, and performing medication reconciliation at every clinical encounter.[5–7] Adding indications to LASA pairs during prescription ordering is a newer, potentially less labor-intensive way to prevent name confusion electronically and make computerized medication ordering safer.[23–28] Drug indications content that is integrated within the electronic health record can allow users to associate indications with drugs being prescribed, dispensed or administered. This may help prevent errors due to choosing the wrong medication because of drug name confusion, as well as facilitate the incorporation of indications in the electronic medical record.[14,22,24–25]

In 2010, the Joint Commission added a LASA requirement to the Medication Management Standards for organizations to identify confused drug name pairs such as the list provided by ISMP.[8] Our study demonstrates that providing information about drug indications could provide organizations and clinicians with another practical tool to prevent drug name confusion errors.

Incorporating indications onto prescription orders and labels might also allow for better medication counseling and potentially empower patients to point out wrong-patient-wrong-medication errors if the reason for use on the medication label is not consistent with their diagnosis.

Limitations

We intentionally used high-level indications rather than granular indications associated with each drug to facilitate indication review and comparison and model an approach to displaying drug indications to prescribers when ordering medications. Thus, our evaluation of indication overlaps is conservative, particularly for anti-infective agents and antineoplastic drugs, where the proxy disease concept was used to represent a single, broad indication for the drug.

Had we reviewed the more granular indications for these drugs, we likely would have had fewer indication overlaps within the drug pairs in our dataset. For example, pazopanib (*Votrient*), is used to treat renal cell carcinoma and advanced soft tissue sarcoma. Ponatinib (*Iclusig*), treats chronic myeloid leukemia or Philadelphia chromosome positive acute lymphoblastic leukemia. However, both drugs were associated with "malignancy" in our data and were categorized as having overlapping indications. Thus, our results are likely an underestimate of the number of LASA drugs that could be distinguished by indications.

Similarly, valacyclovir and valganciclovir were both associated with "viral infection" even though the former treats herpes virus infections and the latter treats infections caused by cytomegalovirus. Use of the proxy disease concept may have been too broad for drug pairs where both constituents were anti-infectives or both were antineoplastic drugs. The level of granularity required to distinguish between indications for these drugs would be a valuable area of further study. Most oncology agents, in particular, have a high likelihood of causing significant patient harm if used in error.[29,30]

Another limitation is that we used a single source of drug indication information rather than cross-referencing multiple sources. The advantage of using the Medknowledge Indications Module was that the content included both FDA-approved and unapproved indications and, once mapped to the products on the ISMP list, could be extracted to a tabular format and reviewed. We used clinician review to evaluate the data for appropriateness and thus felt that the data was valid and appropriate for our study.

We would have liked to have weighted the indications according to the likelihood that a drug would be used for one indication versus another. For example, the most likely indication for regular insulin is diabetes. However, it may also be used with glucose to treat hyperkalemia or as part of a diagnostic procedure to assess cortisol and growth hormone response to hypoglycemic stress. For drug pairs with a partial overlap, defining how common the indication is for a drug could be helpful for determining the likelihood that having an indication associated with the drug would help reduce confusion with a similarly named drug.

We also did not account for how frequently the drug is used. The addition of indications to a drug order or prescription may have more impact in terms of reducing the incidence of inadvertent interchange for commonly prescribed LASA drugs, if associating an indication can differentiate between them. While we are aware that the frequency of prescribing (and how common or uncommon a drug is used) varies among practices and practice settings, we noted that several drug pairs with no overlap in high-level indications were comprised of drugs that were among the top 200 U.S. drugs.[31] Examples include sitagliptin/sumatriptan, tramadol/trazodone, atomoxetine/atorvastatin, metformin/metronidazole, bupropion/buspirone, lamotrigine/levothyroxine, and clonazepam/clonidine. Future studies using real-world drug utilization data in different practice settings would better inform the patient safety and electronic medical record design communities on the impact of associating indications with drugs. Nevertheless, we feel that our results give a good general sense of the potential for indications to reduce medication error.

Additionally, we did not evaluate the relative seriousness of adverse outcomes from confusing two similarly named drugs since some drug mix-ups may not be as dangerous as others; confusing drugs with the same pharmacologic action (e.g., antidiabetic drugs glyburide and glipizide) may be less concerning than confusing two drugs with very different uses (e.g., Keflex for bacterial infection versus Keppra for seizures). These are potential areas for future studies.

The ISMP list is also based on reported errors. Since many errors are unreported, the list is likely an underestimate of LASA drugs. Nevertheless, this study shows that associating indications with prescriptions, even at a general and non-granular level, can provide an additional piece of information that clinicians can use to distinguish between many otherwise confusing drug names. Our findings add to the growing body of literature on the use of indications information to prevent medication errors, guide therapy selection, support medication counseling and education, and facilitate deprescribing of medications.[23–28] Further study is needed on optimal ways of representing drug indications within drug knowledge bases to support different applications of the data (e.g., indications-based prescribing,

Table 2. ISMP confused drug name pairs with *partial overlap* in high-level indications*

Drug A					Drug B					Dice similarity coefficient
Name†	Name type	Active ingredient(s)	Route(s)	Number of high-level indications*	Name†	Name type	Active ingredient(s)	Route(s)	Number of high-level indications*	
Activase	brand	alteplase	IV	4	TNKase	brand	tenecteplase	IV	1	0.40
Activase	brand	alteplase	IV	5	Cathflo Activase	brand	alteplase	injection	2	0.57
Alkeran	brand	melphalan	oral, IV	1	Leukeran	brand	chlorambucil	oral	2	0.67
Alkeran	brand	melphalan	oral, IV	1	Myleran	brand	busulfan	oral	2	0.67
ALPRAZolam	generic	alprazolam	oral	1	LORazepam	generic	lorazepam	oral, injection	11	0.17
aMILoride	generic	amiloride	oral	3	amLODIPine	generic	amlodipine	oral	2	0.40
captopril	generic	captopril	oral	4	carvedilol	generic	carvedilol	oral	3	0.57
carBAMazepine	generic	carbamazepine	oral	4	OXcarbazepine	generic	oxcarbazepine	oral	2	0.67
Cardene	brand	nicardipine		1	Cardizem	brand	diltiazem	oral	3	0.50
CeleXA	brand	citalopram	oral	2	ZyPREXA	brand	olanzapine	oral, IM	5	0.29
clobazam	generic	clobazam	oral	2	clonazePAM	generic	clonazepam	oral	5	0.57
clonazePAM	generic	clonazepam	oral	5	LORazepam	generic	lorazepam	oral, injection	12	0.35
Cymbalta	brand	duloxetine	oral	5	Symbyax	brand	olanzapine/fluoxetine	oral	1	0.33
Depo-Medrol	brand	methylprednisolone	injection	7	Solu-MEDROL	brand	methylprednisolone	injection	8	0.93
Depo-Provera	brand	medroxyprogesterone	IM	2	Depo-subQ Provera 104	brand	medroxyprogesterone	SC	2	0.50
dimenhyDRINATE	generic	dimenhydrinate	oral, injection	2	diphenhydrAMINE	generic	diphenhydramine	oral, injection, topical	11	0.46
DULoxetine	generic	duloxetine	oral	5	FLUoxetine	generic	fluoxetine	oral	8	0.46
Effexor	brand	venlafaxine	oral	5	Effexor XR	brand	venlafaxine	oral	4	0.89
ePHEDrine	generic	ephedrine	oral, injection	2	EPINEPHrine	generic	epinephrine	injection	11	0.31
fentaNYL	generic	fentanyl	transdermal, nasal, sublingual, transmucosal, buccal, epidural	1	SUFentanil	generic	sufentanil	IV	2	0.67
FLUoxetine	generic	fluoxetine	oral	8	PARoxetine	generic	paroxetine	oral	6	0.86
folic acid	generic	folic acid	oral, injection	2	folinic acid (leucovorin calcium)	generic	leucovorin calcium	oral, injection	3	0.40
HumaLOG	brand	insulin lispro	SC	1	HumuLIN	brand	insulin regular	SC	4	0.40
HumuLIN R U-100	brand	insulin regular	SC	4	HumuLIN R U-500	brand	insulin regular	SC	1	0.40
HYDROmorphone	generic	hydromorphone	oral, injection, rectal	1	morphine	generic	morphine	oral, injection, rectal	3	0.50
inFLIXimab	generic	infliximab	IV	3	riTUXimab	generic	rituximab	IV	5	0.25
Isordil	brand	isosorbide dinitrate	oral	2	Plendil	brand	felodipine	oral	3	0.40
ISOtretinoin	generic	isotretinoin	oral	3	tretinoin	generic	tretinoin	oral, topical	4	0.57
Ketalar	brand	ketamine	injection	3	ketorolac	generic	ketorolac	oral, ophthalmic, injection, nasal	3	0.33
ketorolac	generic	ketorolac	oral, ophthalmic, injection, nasal	3	methadone	generic	methadone	oral, injection	2	0.40
lamoTRIgine	generic	lamotrigine	oral	2	levETIRAcetam	generic	levetiracetam	oral, injection	1	0.67
leucovorin calcium	generic	leucovorin calcium	oral, injection	3	levoleucovorin	generic	levoleucovorin	IV	2	0.80
Leukeran	brand	chlorambucil	oral	2	Myleran	brand	busulfan	oral	2	0.50

(continued)

Table 2. continued

Drug A					Drug B					Dice similarity coefficient
Name†	Name type	Active ingredient(s)	Route(s)	Number of high-level indications*	Name†	Name type	Active ingredient(s)	Route(s)	Number of high-level indications*	
levothyroxine	generic	levothyroxine	oral, IV	2	liothyronine	generic	liothyronine	oral	3	0.80
Maxzide	brand	triamterene/hydrochlorothiazide	oral	2	Microzide	brand	hydrochlorothiazide	oral	4	0.67
Metadate CD	brand	methylphenidate	oral	1	Metadate ER	brand	methylphenidate	oral	2	0.67
metoprolol succinate	generic	metoprolol succinate	oral	7	metoprolol tartrate	generic	metoprolol tartrate	oral, IV	7	0.86
mifepristone	generic	mifepristone	oral	3	misoprostol	generic	misoprostol	oral		0.67
mitoMYcin	generic	mitomycin	IV	1	mitoXANTRONE	generic	mitoxantrone	IV	2	0.67
Motrin	brand	ibuprofen	oral	4	Neurontin	brand	gabapentin	oral	5	0.22
Mucinex D	brand	guaifenesin/pseudoephedrine	oral	2	Mucinex DM	brand	guaifenesin/dextromethorphan	oral	1	0.67
niCARdipine	generic	nicardipine	oral, IV	3	NIFEdipine	generic	nifedipine	oral	3	0.67
NovoLIN	brand	insulin regular	SC	3	NovoLOG	brand	insulin aspart	SC	1	0.50
OLANzapine	generic	olanzapine	oral, IM	4	QUEtiapine	generic	quetiapine	oral	4	0.75
opium tincture	generic	opium tincture	oral	2	paregoric (camphorated tincture of opium)	generic	paregoric	oral	1	0.67
PENTobarbital	generic	pentobarbital	oral, injection	3	PHENobarbital	generic	phenobarbital	oral, injection	2	0.40
Plavix	brand	clopidogrel	oral	3	Pradaxa	brand	dabigatran	oral	2	0.40
prednisoLONE	generic	prednisolone	oral, ophthalmic, injection	9	predniSONE	generic	prednisone	oral	7	0.88
Provera	brand	medroxyprogesterone	oral	3	PROzac	brand	fluoxetine	oral	8	0.18
quiNIDine	generic	quinidine	oral, injection	2	quiNINE	generic	quinine	oral	2	0.50
Ritalin LA	brand	methylphenidate	oral	1	Ritalin SR	brand	methylphenidate	oral	2	0.67
Sudafed 12 Hour	brand	pseudoephedrine	oral	1	Sudafed 12 Hour Pressure + Pain	brand	naproxen /pseudoephedrine	oral	3	0.50
TNKase	brand	tenecteplase	IV	1	t-PA	generic	alteplase	injection	5	0.33
Tobradex	brand	tobramycin/dexamethasone	ophthalmic	2	Tobrex	brand	tobramycin	ophthalmic	1	0.67
Topamax	brand	topiramate	oral	5	Toprol-XL	brand	metoprolol succinate	oral	7	0.17
Tylenol	brand	acetaminophen	oral	2	Tylenol PM	brand	acetaminophen/diphenhydramine	oral	4	0.33
Wellbutrin SR	brand	bupropion	oral	4	Wellbutrin XL	brand	bupropion	oral	3	0.57
ZyrTEC	brand	cetirizine	oral	4	ZyrTEC-D	brand	cetirizine /pseudoephedrine	oral	2	0.67

*disease concept grouping or disease concept proxy

†Drug A and Drug B names are as represented on ISMP's list of confused drug names

IM = intramuscular, IV= intravenous, SC = subcutaneous

Table 3. ISMP confused drug name pairs with *complete overlap* in high-level indications*

Drug A				Drug B				Number of high-level indications within pair*
Name†	Name type	Active ingredient(s)	Route(s)	Name†	Name type	Active ingredient(s)	Route(s)	
Abelcet	brand	amphotericin b lipid complex	IV	amphotericin B	generic	amphotericin b	IV	1
Adacel (Tdap)	brand	diphtheria,pertussis(acellular),tetanus vaccine	IM	Daptacel (DTaP)	brand	diphtheria, pertussis (acell), tetanus pediatric vaccine	IM	1
ado-trastuzumab emtansine	generic	ado-trastuzumab emtansine	IV	trastuzumab	generic	trastuzumab	IV	1
Ambisome	brand	amphotericin b liposome	IV	amphotericin B	generic	amphotericin b	IV	1
Avandia	brand	rosiglitazone	oral	Prandin	brand	repaglinide	oral	1
Bicillin C-R	brand	penicillin g benzathine/penicillin g procaine	IM	Bicillin L-A	brand	penicillin g benzathine	IM	1
CARBOplatin	generic	carboplatin	IV	CISplatin	generic	cisplatin	IV	1
ceFAZolin	generic	cefazolin	injection	cefTRIAXone	generic	ceftriaxone	injection	1
coagulation factor IX (recombinant)	generic	factor IX human recombinant	IV	factor IX complex, vapor heated	generic	factor IX complex, prothrombin complex concentrate, 3-factor	IV	1
DAUNOrubicin	generic	daunorubicin	IV	DAUNOrubicin citrate liposomal	generic	daunorubicin citrate liposomal	IV	1
DAUNOrubicin	generic	daunorubicin	IV	DOXOrubicin	generic	doxorubicin	IV	1
DAUNOrubicin	generic	daunorubicin	IV	IDArubicin	generic	idarubicin	IV	1
Dilaudid	brand	hydromorphone	oral, injection	Dilaudid-5	brand	hydromorphone	oral	1
DOXOrubicin	generic	doxorubicin	IV	DOXOrubicin liposomal	generic	doxorubicin pegylated liposomal	IV	1
DOXOrubicin	generic	doxorubicin	IV	IDArubicin	generic	idarubicin	IV	1
Dulcolax (bisacodyl)	brand	bisacodyl	oral, rectal	Dulcolax (docusate sodium)	brand	docusate sodium	oral	1
Engerix-B adult	brand	hepatitis b virus vaccine recombinant	IM	Engerix-B pediatric/adolescent	brand	hepatitis b virus vaccine recombinant	IM	1
epirubicin	generic	epirubicin	IV	eribulin	generic	eribulin	IV	1
Fioricet	brand	butalbital/acetaminophen/caffeine	oral	Fiorinal	brand	butalbital/aspirin/caffeine	oral	1
glipiZIDE	generic	glipizide	oral	glyBURIDE	generic	glyburide	oral	1
HumaLOG	brand	insulin lispro	SC	NovoLOG	brand	insulin aspart	SC	1
HumaLOG Mix 75/25	brand	insulin lispro protamine and insulin lispro	SC	HumuLIN 70/30	brand	insulin NPH / insulin regular	SC	1
HYDROcodone	generic	hydrocodone	oral	oxyCODONE	generic	oxycodone	oral	1
Janumet	brand	sitagliptin /metformin	oral	Januvia	brand	sitagliptin	oral	1
Menactra	brand	meningococcal vaccine a,c,y,w-135,diphtheria toxoid conjugate	IM	Menomune	brand	meningococcal vaccine a,c,y,w-135	SC	1
morphine – non-concentrated oral liquid	generic	morphine	oral	morphine – oral liquid concentrate	generic	morphine	oral	1
MS Contin	brand	morphine	oral	OxyCONTIN	brand	oxycodone	oral	1
NovoLIN 70/30	brand	insulin NPH / insulin regular	SC	NovoLOG Mix 70/30	brand	insulin aspart protamine / insulin aspart	SC	1

(continued)

Table 3. continued

Drug A				Drug B				Number of high-level indications within pair*
Name†	Name type	Active ingredient(s)	Route(s)	Name†	Name type	Active ingredient(s)	Route(s)	
NovoLOG FLEXPEN	brand	insulin aspart	SC	NovoLOG Mix 70/30 FLEXPEN	brand	insulin aspart protamine /insulin aspart	SC	1
oxyCODONE	generic	oxycodone	oral	OxyCONTIN	brand	oxycodone	oral	1
PACLitaxel	generic	paclitaxel	IV	PACLitaxel protein-bound particles	generic	paclitaxel protein-bound	IV	1
pazopanib	generic	pazopanib	oral	ponatinib	generic	ponatinib	oral	1
PEMEtrexed	generic	pemetrexed	IV	PRALAtrexate	generic	pralatrexate	IV	1
Renagel	brand	sevelamer	oral	Renvela	brand	sevelamer	oral	1
Rifadin	brand	rifampin	oral, IV	Rifater	brand	rifampin/isoniazid/pyrazinamide	oral	1
Rifamate	brand	rifampin/isoniazid	oral	rifampin	generic	rifampin	oral, IV	1
Sudafed	brand	pseudoephedrine	oral	Sudafed PE	brand	phenylephrine	oral	1
SUMAtriptan	generic	sumatriptan	oral, nasal, SC, transdermal	ZOLMitriptan	generic	zolmitriptan	oral, nasal	1
Taxol	brand	paclitaxel	IV	Taxotere	brand	docetaxel	IV	1
TOLAZamide	generic	tolazamide	oral	TOLBUTamide	generic	tolbutamide	oral	1
valACYclovir	generic	valacyclovir	oral	valGANciclovir	generic	valganciclovir	oral	1
Valcyte	brand	valganciclovir	oral	Valtrex	brand	valacyclovir	oral	1
vinBLAStine	generic	vinblastine	IV	vinCRIStine	generic	vincristine	IV	1
Viracept	brand	nelfinavir	oral	Viramune	brand	nevirapine	oral	1
Adderall	brand	dextroamphetamine /amphetamine	oral	Adderall XR	brand	dextroamphetamine /amphetamine	oral	2
Claritin-D	brand	loratadine/pseudoephedrine	oral	Claritin-D 24	brand	loratadine/pseudoephedrine	oral	2
Retrovir	brand	zidovudine	oral, IV	ritonavir	generic	ritonavir	oral	2
Depakote	brand	divalproex	oral	Depakote ER	brand	divalproex	oral	3
HumuLIN	brand	insulin regular	SC	NovoLIN	brand	insulin regular	SC	4
Lupron Depot-3 Month	brand	leuprolide	IM	Lupron Depot-Ped	brand	leuprolide	IM	4
Ortho Tri-Cyclen	brand	norgestimate-ethinyl estradiol	oral	Ortho Tri-Cyclen LO	brand	norgestimate-ethinyl estradiol	oral	4
SEROquel	brand	quetiapine	oral	SEROquel XR	brand	quetiapine	oral	4
TEGretol	brand	carbamazepine	oral	TEGretol XR	brand	carbamazepine	oral	4
Yasmin	brand	ethinyl estradiol/drospirenone	oral	Yaz	brand	ethinyl estradiol/drospirenone	oral	4
Solu-CORTEF	brand	hydrocortisone	injection	Solu-MEDROL	brand	methylprednisolone	injection	8

*disease concept grouping or disease concept proxy

†Drug A and Drug B names are as represented on the ISMP's list of confused drug names

IM = intramuscular, IV= intravenous, SC = subcutaneous

patient problem list maintenance, drug regimen review, claims adjudication).[32] More research is also needed on practical ways to integrate indications content within the electronic health record such that clinicians can associate a drug's indication easily and accurately at any point in the medication use process.

CONCLUSION

Indications can help differentiate the majority of drugs with look-alike-sound-alike names in the current version of the ISMP list, and thus may potentially be used to reduce harm from errors that occur from drug name confusion. Further studies are needed to assess the optimal structuring of indications content, the impact of adding indications to drug prescriptions, and optimal ways to integrate indications content into electronic medication ordering systems and other areas of the clinical workflow.

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COMPETING INTERESTS

Dr Cheng is employed by First Databank Inc. All other authors have no competing interests to declare.

CONTRIBUTORS

Dr Cheng was involved in the study design, data acquisition, analysis, interpretation, and drafting of the manuscript. Drs Salazar and Amato were involved with the design, data validation, data analysis, and critical review of the manuscript. Dr Lambert was involved with the study design, and critical review of the manuscript. Ms. Volk was involved with the study design, data analysis and critical review of the manuscript. Dr Schiff was involved with the study design, data analysis, and critical review of the manuscript. All authors approved of the final manuscript version.

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