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Extemporaneous compounding practices: Case study in Thai Hospitals

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Abstract

Objective: To collect and analyze information on extemporaneous compounding practices in Thai hospitals and compare stability data from previous studies and reports. **Methods:** This study has focused on collaborative hospitals that had been using specific extemporaneous formulations for over a year without reported adverse effects whilst also documenting stability data. This study involved data collection from three hospitals and comparing their extemporaneous preparations with additional data from academic journals and reports. Data were analyzed using descriptive statistics. **Results:** Three hospitals participated in this study. Each hospital produced a notable quantity of extemporaneous formulations; Hospitals A and B each reported 50 and 52 formulations, respectively, whereas Hospital C reported 50. These formulations span various types, including oral liquids, solids, and eye drops. This study identified several key areas of variation among the extemporaneous formulations produced by participating hospitals. These differences include storage and stability conditions, dosage forms, vehicles used, and strength of the medications. **Conclusion:** This study highlights significant variability in extemporaneous compounding practices across Thai hospitals. This underscores the need for standardized guidelines to ensure the consistent quality and safety of compounded medications. Establishing uniform protocols can help optimize therapeutic outcomes and enhance the stability and efficacy of extemporaneously prepared medications, ultimately improving patient care in hospital settings. In addition, sharing best practices and stability data among hospitals could further refine compounding techniques and medication management.

Keywords: Extemporaneous preparations; Thai hospitals

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INTRODUCTION

The World Health Organization (WHO) has stated that the concept of using medicines rationally has progressed to focus on their quality use. This approach emphasizes the importance of making sure that all patients have access to the right medicines, which are safe, effective, and of good quality, at the right time and dosage, and at an affordable price.[1] Extemporaneous preparation, defined by the US FDA, involves customizing drug formulations to meet individual patient needs through mixing or altering ingredients.[2] This process, called extemporaneous compounding, involves preparing medicines for patients when commercial options are unavailable. It typically involves small-scale production using raw materials or existing drugs in order

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to create an appropriate dosage and strength for a specific patient.[3, 4]

The practice of extemporaneous formulation, which involves the customization of medications to suit the unique needs of individual patients, displays considerable variation across different healthcare settings. This variation can be attributed to a multitude of factors, including institutional policies, availability of resources, and the level of expertise of healthcare professionals engaged in the compounding procedure.[5-7] Exploration of extemporaneous compounding highlights its intricate nature, which is steeped in history, yet this exploration constantly adapts to meet modern healthcare demands. This practice is crucial for creating personalized medications where standard products fail, particularly in dermatology and pediatrics. However, it faces significant challenges such as ensuring consistency across batches and maintaining high quality and safety standards. The lack of standardized formulas and precise documentation complicates this process, increasing the risk of errors and inconsistencies that could affect patient outcomes. To address these issues, rigorous quality control measures and comprehensive regulatory oversight are essential to ensure that each compound is safe and effective. This ongoing effort requires collaboration between pharmacists, healthcare providers, and regulatory bodies in order to foster a culture of meticulous care and continuous improvements in the field of extemporaneous compounding.[8-11]

The prevalence of compounded medications is significant in developing nations owing to the varying economic, social, and industrial conditions present. These nations, representing more than 85% of the global population, include Central and South America, Africa, and most of Asia. In Indonesia, compounded medications are particularly common for pediatric care, with a high percentage of medications for children being custom-made.[12-14] Similar trends are observed in other countries such as Brazil and Estonia, particularly in neonatal and pediatric care, where off-label and extemporaneous drugs are frequently utilized.[15-17] In Jordan, a survey of 223 pharmacies revealed that over half of them practice extemporaneous compounding, mainly for dermatological uses, due to the lack of commercially available options.[7] Commonly compounded forms are creams and ointments. Challenges include insufficient orders and a lack of necessary equipment, with pharmacies often depending on physician orders or in-house protocols for compounding instructions and expiration determinations.[7] In Queensland, Australia, efforts to understand and enhance extemporaneous compounding align with the national medicine policies present, aiming to improve the quality, safety, and efficacy of these preparations through potential central manufacturing solutions.[18]

These examples underline the global challenge of extemporaneous compounding and highlight the need for standardized protocols and international collaboration to ensure high-quality, safe, and effective preparation.

In Thailand, hospital pharmacy standards mandate that the pharmacists or adequately trained personnel must prepare the extemporaneous compounds—medications that are not commercially available but necessary for patient care—focusing on scientific principles, quality, and safety.[19, 20] Regular reviews of these formulas are essential in order to address challenges, especially those arising from limited information exchange. Unlike pharmaceutical manufacturing, compounding in Thai hospitals is exempt from many of the current Good Manufacturing Practices (cGMP), allowing a more tailored approach to patient medication. Past studies, including those by Jaidee in 1984 and Pitchayajittipong et al. in 2019, showed that a significant number of Thai hospitals engage in pharmaceutical production, with extemporaneous preparations forming a substantial part of their pharmaceutical offerings, highlighting the critical role of personalized medication in Thailand's healthcare system.[19, 21-24] Another survey conducted among 88 hospitals in Thailand highlighted the widespread use of extemporaneous compounding, varying significantly in preparations such as oral liquids, semisolids, and eye preparations. The hospitals faced challenges related to space, personnel, skills, raw materials, and a lack of standardized formulas.[24]

However, studies on the characteristics and stability of extemporaneous compounding formulas are lacking. Therefore, this study has aimed to collect and analyze information on extemporaneous compounding practices in Thai hospitals and compare stability data from previous studies and reports.

METHODS

Study population

This study focused on hospitals that were open to collaboration by sharing data on specific extemporaneous preparations. The inclusion criteria were hospitals that had been using particular extemporaneous prescription formulations for at least one year without any reported adverse effects and documented the stability of these extemporaneous products. Ethical approval was granted by the Research Ethics Committee of Ubon Ratchathani University (No. UBU – REC – 22/2563).

Study design

This study compared extemporaneous formulations from three hospitals, alongside additional formulations from prior academic journal reports, such as PubMed, ScienceDirect, and Thai Journals Online (ThaiJO). This comparison assessed various dimensions including pharmaceutical formulation, generic name, indication, dosage form, strength, storage conditions, stability, ingredients, types of diluents or excipients, and the preparation process. Following this comparative analysis, extraction and analysis of data was performed according to topics related to the hospital's specific extemporaneous prescription formulas. The findings were systematically recorded in Microsoft Excel, as described below.

Data collection and analysis

The comparative analysis included data input from two sources: 1. Extemporaneous compounding formulas from the three hospitals that participated in the study and, 2. Stability information from previous studies or reports in academic

journals. Each formulation was compared based on general formulation information, specific formulation details, strength, dosage form, the procedures and techniques used during compounding, storage conditions, and stability. Descriptive statistical methods were used to analyze and interpret the data.

RESULTS

Hospital characteristics and types of extemporaneous preparations from hospitals

There were three hospitals that participated in this study. Hospitals A and C were categorized as regional hospitals, whereas Hospital B operated as a general hospital. These surveys were conducted under the Ministry of Public Health (MOPH). The bed capacity varied significantly between the hospitals: Hospital A had 1,188 beds, Hospital C had 798 beds, and Hospital B had the fewest beds (250 beds). Table 1 provides a comparative overview of the three hospitals labeled Hospitals A, B, and C, highlighting the differences in structure, staffing, and pharmacy capabilities.

In terms of extemporaneous formulations, Hospitals A and B offered a similar range of oral liquid preparations, each providing more suspensions than Hospital C. Hospital A produced 36 suspensions, Hospital B 38, while Hospital C only had 4. For syrups, Hospital A offered 2 types, Hospital B had 3, and Hospital C provided 2. Solutions were more evenly distributed with Hospital A producing 3, Hospital B 2, and Hospital C 4. None of the hospitals produced drops or elixirs.

Regarding eye drops, Hospitals A and B produced the same number of eye drops and subconjunctival antibiotics, with each offering 5 eye drops and 4 subconjunctival antibiotics. In contrast, Hospital C had a slightly higher number of eye drops (6) but only 1 type of subconjunctival antibiotic.

When it came to solid extemporaneous preparations, only Hospital C produced these, offering a unique selection of 31 powders and 2 types of granules. Hospitals A and B did not produce any solid preparations.

Overall, Hospital A produced 50 types of formulations, Hospital B produced 52, and Hospital C produced 50, underscoring the variability in pharmaceutical services provided by each institution.

Extemporaneous formulations

Table 2 illustrates the diversity of extemporaneous preparations with varying storage and stability conditions across the three hospitals, reflecting the tailored approaches to medication management and patient care. For example, acetazolamide, used to reduce intraocular pressure, was available in suspension form at Hospitals A and B and in a powder form at Hospital C, with the stability varying from 7 to 90 days depending on the form and hospital.

Table 3 presents a comparative analysis of ten extemporaneous preparations from the three hospitals, aligning the current practices with those documented in earlier studies. The specific details of the formulations and also the storage conditions are provided to illustrate these comparisons.

For instance, details of some formulations and their storage are provided as follows:

Table 1. Characteristics of the respondents (n=3).

Characteristics	Hospital A	Hospital B	Hospital C
1. Types of the hospital	Regional hospitals	General hospitals	Regional hospitals
2. Number of beds	1,188	250	798
3. Pharmacy workforce in the production department			
3.1 Number of pharmacists	2	1	2
3.2 Number of pharmacy technicians	2	2	2
Total	4	3	4
4. Number of extemporaneous formulations			
4.1 Oral liquid extemporaneous preparations			
- Suspensions	36	38	4
- Syrups	2	3	2
- Solutions	3	2	4
4.2 Eye drops			
- Eye drops	5	5	6
- Subconjunctival antibiotics	4	4	1
4.3 Solid extemporaneous preparations			
- Powders	0	0	31
- Granules	0	0	2
Total	50	52	50

Table 2. Extemporaneous preparations from three hospitals.

	List of medicines	Indication	Hospital A	Hospital B	Hospital C
1.	Acetazolamide	Reduction of intra-ocular pressure in open-angle glaucoma, secondary glaucoma and peri-operatively in angle-closure glaucoma	Acetazolamide suspensions 10 mg/ml (50 ml/bottles)	Acetazolamide suspensions 10 mg/ml (50 ml/bottles)	Powders
	Storage & Stability		Refrigerated 2-8°C, 7 days	Refrigerated 2-8°C, 30 days	90 days
2.	Acyclovir	Treatment of genital herpes, herpes zoster, and varicella in immunocompetent individuals	Acyclovir suspensions 20 mg/ml (20 ml/bottles)	Acyclovir suspensions 20 mg/ml (20 ml/bottles)	Powders
	Storage & Stability		Refrigerated 2-8°C, 14 days	Refrigerated 2-8°C, 14 days	90 days
3.	Allopurinol	Gout or uric acid and calcium oxalate renal stones	Allopurinol suspensions 10 mg/ml (30 ml/bottles)	Allopurinol suspensions 10 mg/ml (30 ml/bottles)	Powders
	Storage & Stability		Refrigerated 2-8°C, 30 days	Refrigerated 2-8°C, 30 days	90 days
4.	Alprostadil	To promote dilation of ductus arteriosus in infants with congenital heart disease dependent on ductal shunting for oxygenation/perfusion	N/A	N/A	Alprostadil sterile solutions (Prostaglandin E1) (1 mcg/bottle)
	Storage & Stability		N/A	N/A	Store in a refrigerator, 14 days
5.	Amikacin	Treatment of infections	Amikacin ophthalmic solutions 20 mg/ml (10 ml/bottles)	Amikacin ophthalmic solutions 20 mg/ml (10 ml/bottles)	Amikacin ophthalmic solutions 20 mg/ml, 50 mg/ml (10 ml/bottle) ED
	Storage & Stability		Store at 2-8°C, 24 hours	Store at 2-8°C, 24 hours	Store in a refrigerator, 7 days
6.	Aminophylline	Antiasthmatic and COPD Preparations	Aminophylline solutions 10 mg/ml (25 ml/bottles)	Aminophylline solutions 10 mg/ml (25 ml/bottles)	Aminophylline solutions 5 mg/ml (50 ml/bottle), Powders
	Storage & Stability		Seal the lid, label, and store in a refrigerated cabinet at 2-8°C, 30 days	Seal the lid, label, and store in a refrigerated cabinet at 2-8°C, 30 days	Solution: N/A, Powders: 90 days
7.	Amiodarone	Arrhythmias	Amiodarone suspensions 5 mg/ml (40 ml/bottles)	Amiodarone suspensions 5 mg/ml (40 ml/bottles)	Amiodarone powders
	Storage & Stability		Seal the lid, label, and store in a refrigerated cabinet at 2-8°C, 30 days	Seal the lid, label, and store in a refrigerated cabinet at 2-8°C, 30 days	90 days
8.	Amlodipine	Hypertension or angina	Amlodipine suspensions 1 mg/ml (30 ml/bottles)	Amlodipine suspensions 1 mg/ml (30 ml/bottles)	Amlodipine powders
	Storage & Stability		Seal the lid, label, and store in a refrigerated cabinet at 2-8°C,30 days	Seal the lid, label, and store in a refrigerated cabinet at 2-8°C, 30 days	90 days
9.	Amphotericin B eye drops	Treatment of infections	Amphotericine-B eye drops, 3 mg/ml (5 ml/bottles)	Amphotericine-B eye drops, 3 mg/ml (5 ml/bottles)	Amphotericine-B eye drops, 0.3% (5 ml/bottles)
	Storage & Stability		Refrigerated 2-8°C, 14 days	Refrigerated 2-8°C, 14 days	Refrigerated 2-8°C, 7 days
10.	Amphotericin B subconjunctival antibiotics	Treatment of infections	Amphotericin-B subconjunctival antibiotics 0.75 mg/0.5 ml	Amphotericin-B subconjunctival antibiotics 0.75 mg/0.5 ml	Amphotericin-B subconjunctival antibiotics 0.5%
	Storage & Stability		N/A	N/A	Refrigerated 2-8°C, 7 days
11.	Atenolol	Hypertension, angina pectoris, myocardial infarction and arrhythmias	Atenolol suspensions 2 mg/ml (25 ml/bottles)	Atenolol suspensions 2 mg/ml (25 ml/bottles)	Atenolol powders

	Storage & Stability		Seal the lid, label, and store in a refrigerated cabinet at 2-8°C, 21 days	Seal the lid, label, and store in a refrigerated cabinet at 2-8°C, 21 days	90 days
12.	Baclofen	Spasticity of the skeletal muscle	Baclofen suspensions 2 mg/ml (30 ml/bottles)	Baclofen suspensions 2 mg/ml (30 ml/bottles)	Baclofen powders
	Storage & Stability		Seal the lid, label, and store in a refrigerated cabinet at 2-8°C, 30 days	Seal the lid, label, and store in a refrigerated cabinet at 2-8°C,30 days	90 days
13.	Captopril	Hypertension, congestive heart failure, post-myocardial infarction, diabetic nephropathy	Captopril suspensions 1 mg/ml (25 ml/bottles)	Captopril suspensions 1 mg/ml (25 ml/bottles)	Captopril powders
	Storage & Stability		Seal the lid, label, and store in a refrigerated cabinet at 2-8°C, 7 days	Seal the lid, label, and store in a refrigerated cabinet at 2-8°C, 7 days	90 days
14.	Cefazolin eye drops	Treatment of infections	Cefazolin eye drops, 50 mg/ml (5 ml/bottles)	Cefazolin eye drops, 50 mg/ml (5 ml/bottles)	Cefazolin eye drops, 33 mg/ml, 50 mg/ml (10 ml/bottles)
	Storage & Stability		Refrigerated 2-8°C, 14 days	Refrigerated 2-8°C, 14 days	Freezer, 30 days
15.	Cefazolin subconjunctival antibiotics	Treatment of infections	Cefazolin subconjunctival antibiotics 100 mg/0.5 ml, 125 mg/0.5 ml	Cefazolin subconjunctival antibiotics 100 mg/0.5 ml, 125 mg/0.5 ml	N/A
	Storage & Stability		N/A	N/A	N/A
16.	Ceftazidime eye drops	Treatment of infections	Ceftazidime eye drops, 50 mg/ml (5 ml/bottles)	Ceftazidime eye drops, 50 mg/ml (5 ml/bottles)	Ceftazidime eye drops, 50 mg/ml (5 ml/bottles)
	Storage & Stability		Refrigerated 2-8°C, 14 days	Refrigerated 2-8°C, 14 days	Refrigerated 2-8°C, 7 days
17.	Ceftazidime subconjunctival antibiotics	Treatment of infections	Ceftazidime subconjunctival antibiotics	Ceftazidime subconjunctival antibiotics 100 mg/0.5 ml	N/A
	Storage & Stability		N/A	N/A	N/A
18.	Chloroquine	Treatment of malaria - acute attack	Chloroquine (base) suspensions 9 mg/ml (50 ml/bottles)	Chloroquine (base) suspensions 9 mg/ml (50 ml/bottles)	Chloroquine powders
	Storage & Stability		Seal the lid, label, and store in a refrigerated cabinet at 2-8°C, 30 days	Seal the lid, label, and store in a refrigerated cabinet at 2-8°C, 30 days	90 days
19.	Ciprofloxacin	Treatment of infections	Ciprofloxacin suspensions 50 mg/ml (30 ml/bottles)	Ciprofloxacin suspensions 50 mg/ml (30 ml/bottles)	Ciprofloxacin powders
	Storage & Stability		Seal the lid, label, and store in a refrigerated cabinet at 2-8°C, 7 days	Seal the lid, label, and store in a refrigerated cabinet at 2-8°C, 7 days	90 days
20.	Cisapride	Non-ulcer dyspepsia, GERD	Cisapride suspensions 1 mg/ml (30 ml/bottles)	Cisapride suspensions 1 mg/ml (30 ml/bottles)	Cisapride powders
	Storage & Stability		Seal the lid, label, and store in a refrigerated cabinet at 2-8°C, 30 days	Seal the lid, label, and store in a refrigerated cabinet at 2-8°C, 30 days	90 days
21.	Clindamycin	Treatment of infections	Clindamycin suspensions 20 mg/ml (30 ml/bottles)	Clindamycin suspensions 20 mg/ml (30 ml/bottles)	Clindamycin powders
	Storage & Stability		Seal the lid, label, and store in a refrigerated cabinet at 2-8°C, 30 days	Seal the lid, label, and store in a refrigerated cabinet at 2-8°C, 30 days	90 days
22.	Clonazepam	Epilepsy, non-epileptic myoclonus	Clonazepam suspensions 0.1 mg/ml (20 ml/bottle)	Clonazepam suspensions 0.1 mg/ml (20 ml/bottle)	Clonazepam powders
	Storage & Stability		Amber glass bottles, sealed, labeled, and refrigerated at 2-8°C, 30 days	Amber glass bottles, sealed, labeled, and refrigerated at 2-8°C, 30 days	90 days

23.	Dapsone	Leprosy, dermatitis herpetiformis	Dapsone suspensions 5 mg/ml (20 ml/bottle)	Dapsone suspensions 5 mg/ml (20 ml/bottle)	Dapsone powders
	Storage & Stability		Amber glass bottles, sealed, labeled, and refrigerated at 2-8°C, 30 days	Amber glass bottles, sealed, labeled, and refrigerated at 2-8°C, 30 days	90 days
24.	Diazepam	Anxiety, alcohol withdrawal and seizures	Diazepam suspensions 1 mg/ml (20 ml/bottle)	Diazepam suspensions 1 mg/ml (20 ml/bottle)	Diazepam powders
	Storage & Stability		Amber glass bottles, sealed, labeled, and refrigerated at 2-8°C, 30 days	Amber glass bottles, sealed, labeled, and refrigerated at 2-8°C, 30 days	90 days
25.	Enalapril	Hypertension, congestive heart failure	Enalapril suspensions 1 mg/ml (20 ml/bottle)	Enalapril suspensions 1 mg/ml (20 ml/bottle)	Enalapril Suspensions 1 mg/ml (30 ml/bottle)
	Storage & Stability		Amber glass bottles, sealed, labeled, and refrigerated at 2-8°C, 30 days	Amber glass bottles, sealed, labeled, and refrigerated at 2-8°C, 30 days	Refrigerated 2-8°C, 30 days
26.	Ethambutol	Tuberculosis	Ethambutol suspensions 50 mg/ml (40 ml/bottle)	Ethambutol suspensions 50 mg/ml (40 ml/bottle)	Ethambutol powders
	Storage & Stability		Amber glass bottles, sealed, labeled, and refrigerated at 2-8°C, 30 days	Amber glass bottles, sealed, labeled, and refrigerated at 2-8°C, 30 days	90 days
27.	Fluconazole	Antifungal Drug	Fluconazole solutions10 mg/ml	Fluconazole suspensions 1 mg/mL	Fluconazole Powders
	Storage & Stability		Refrigerated 2-8°C, 15 days	Refrigerated 2-8°C, 15 days	90 days
28.	Furosemide	Diuretics	Furosemide syrups 2 mg/ml (60 ml/bottle)	Furosemide syrups 2 mg/ml (60 ml/bottle)	Furosemide Suspensions 1 mg/ml (60 ml/bottle)
	Storage & Stability		Amber glass bottles, sealed, labeled, and refrigerated at 2-8°C, 7 days	Amber glass bottles, sealed, labeled, and refrigerated at 2-8°C, 7 days	30 days
29.	Hydrochlorothaizide	Hypertension, edema, nephrogenic diabetes insipidus, congestive cardiac failure	Hydroxychlorothaizide Suspensions 20 mg/ml	Hydroxychlorothaizide Suspensions 20 mg/ml	Hydroxychlorothaizide powders
	Storage & Stability		Seal the lid, label, and store in a refrigerated cabinet at 2-8°C, 30 days	Seal the lid, label, and store in a refrigerated cabinet at 2-8°C, 30 days	90 days
30.	Hydroxychloroquine	Treat or prevent malaria	Hydroxychloroquine Suspensions 20 mg/ml (20 ml/bottle)	Hydroxychloroquine Suspensions 20 mg/ml (20 ml/bottle)	Hydroxychloroquine powders
	Storage & Stability		Seal the lid, label, and store in a refrigerated cabinet at 2-8°C, 30 days	Seal the lid, label, and store in a refrigerated cabinet at 2-8°C, 30 days	90 days
31.	Iloprost	Pulmonary arterial hypertension (PAH)	N/A	N/A	Iloprost injection solutions 1 mcg/ampule
	Storage & Stability		N/A	N/A	Store in a conventional refrigerator, 7 days
32.	Indomethacin	Closure of ductus arteriosus	Indomethacin suspensions 1 mg/ml (25 ml/bottle)	Indomethacin suspensions 1 mg/ml (25 ml/bottle)	Indomethacin
	Storage & Stability		Seal the lid, label, and store in a refrigerated cabinet at 2-8°C, 30 days	Seal the lid, label, and store in a refrigerated cabinet at 2-8°C, 30 days	90 days
33.	Isoniazid	Tuberculosis	Isoniazid suspensions 10 mg/ml (30 ml/bottle)	Isoniazid suspensions 10 mg/ml (30 ml/bottle)	N/A
	Storage & Stability		Refrigerated 2-8°C, 21 days	Refrigerated 2-8°C, 21 days	N/A
34.	Itraconazole	Fungal infection	Itraconazole suspensions 10 mg/ml (30 ml/bottle)	Itraconazole suspensions 10 mg/ml (30 ml/bottle)	Itraconazole granules

	Storage & Stability		Seal the lid, label, and store in a refrigerated cabinet at 2-8°C, 14 days	Seal the lid, label, and store in a refrigerated cabinet at 2-8°C, 14 days	90 days
35.	Ketoconazole	Fungal infection	Ketoconazole Suspensions 10 mg/ml (20 ml/bottle)	Ketoconazole Suspensions 10 mg/ml (20 ml/bottle)	Ketoconazole powders
	Storage & Stability		Seal the lid, label, and store in a refrigerated cabinet at 2-8°C, 7 days	Seal the lid, label, and store in a refrigerated cabinet at 2-8°C, 7 days	90 days
36.	Mercaptopurine	Acute lymphoblastic leukemia, lymphoma, Non-Hodgkin lymphoma	N/A	N/A	Mercaptopurine (6-MP) suspensions 20 mg/ml (50 ml/bottle)
	Storage & Stability		N/A	N/A	Store in a refrigerator, 90 days
37.	Methimazole	Hyperthyroidism	Methimazole Suspensions 3 mg/ml (20 ml/bottle)	N/A	Methimazole powders
	Storage & Stability		Seal the lid, label, and store in a refrigerated cabinet at 2-8°C 7 days	N/A	90 days
38.	Metoclopramide	To facilitate gastric emptying and gastrointestinal motility, Apnea of prematurity	Metoclopramide solutions 0.1 mg/ml (30 ml/bottle)	Metoclopramide solutions 0.1 mg/ml (30 ml/bottle)	N/A
	Storage & Stability		Seal the lid, label, and store in a refrigerated cabinet at 2-8°C, 30 days	Seal the lid, label, and store in a refrigerated cabinet at 2-8°C, 30 days	N/A
39.	Metronidazole	Amoebiasis, giardiasis	Metronidazole suspensions 50 mg/ml (24 ml/bottle)	N/A	Metronidazole powders
	Storage & Stability		Refrigerated 2-8°C, 30 days	N/A	90 days
40.	Neomycin	Treatment of infections	Neomycin suspensions	Neomycin suspensions 100 mg/ml (28 ml/bottle)	Neomycin powders
	Storage & Stability		Refrigerated 2-8°C, 7 days	Refrigerated 2-8°C, 7 days	90 days
41.	Nitrazepam	Insomnia and management of infantile spasms	Nitrazepam suspensions 1 mg/ml (20 ml/bottles)	Nitrazepam suspensions 1 mg/ml (20 ml/bottles)	Nitrazepam powders
	Storage & Stability		Refrigerated 2-8°C, 30 days	Refrigerated 2-8°C, 30 days	90 days
42.	Omeprazole	Reflux oesophagitis, eradication of H. Pylori infection, benign peptic ulcer not responding to conventional therapy, Zollinger-Ellison Syndrome	Omeprazole suspensions 2 mg/ml (20 ml/bottles)	Omeprazole suspensions 2 mg/ml (20 ml/bottles)	Omeprazole granules
	Storage & Stability		Refrigerated 2-8°C, 30 days	Refrigerated 2-8°C, 30 days	90 days
43.	Oseltamivir suspensions	Influenza	Oseltamivir suspensions 10 mg/ml (240 ml/bottles)	Oseltamivir suspensions 10 mg/ml (240 ml/bottles)	N/A
	Storage & Stability		Refrigerated 2-8°C, 30 days	Refrigerated 2-8°C, 30 days	N/A
44.	Oseltamivir syrups	Influenza	N/A	Oseltamivir syrups 7.5 mg/ml (40 ml/bottles)	Oseltamivir syrups 10 mg/ml (60 ml/bottle)
	Storage & Stability		N/A	Refrigerated 2-8°C, 28 days	Refrigerated 2-8°C, 10 days
45.	Phenytoin	Epilepsy	Phenytoin suspensions 10 mg/ml (50 ml/bottles)	Phenytoin suspensions 10 mg/ml (50 ml/bottles)	Phenytoin powders
	Storage & Stability		Refrigerated 2-8°C, 30 days	Refrigerated 2-8°C, 30 days	90 days

46.	Primaquine	Preventing relapse of P.vivax and P.ovale, malaria prophylaxis	Primaquine suspensions 1 mg/ml (30 ml/bottles)	Primaquine suspensions 1 mg/ml (30 ml/bottles)	Primaquine powders
	Storage & Stability		Refrigerated 2-8°C, 15 days	Refrigerated 2-8°C, 15 days	90 days
47.	Propranolol	Dysrhythmias, tachycardia, hypertrophic obstructive cardiomyopathy (For cardiologist only)	Propranolol suspensions 2 mg/ml (20 ml/bottles)	Propranolol suspensions 2 mg/ml (20 ml/bottles)	Propranolol powders
	Storage & Stability		Refrigerated 2-8°C, 30 days	Refrigerated 2-8°C, 30 days	90 days
48.	Pyrazinamide	Tuberculosis	Pyrazinamide suspensions 40 mg/ml (25 ml/bottles)	Pyrazinamide suspensions 40 mg/ml (25 ml/bottles)	Pyrazinamide powders
	Storage & Stability		Refrigerated 2-8°C, 30 days	Refrigerated 2-8°C, 30 days	90 days
49.	Pyrimethamine	Toxoplasma, malaria treatment	Pyrimethamine suspensions 4 mg/ml (25 ml/bottles)	Pyrimethamine suspensions 4 mg/ml (25 ml/bottle)	Pyrimethamine powders
	Storage & Stability		Refrigerated 2-8°C, 30 days	Refrigerated 2-8°C, 30 days	90 days
50.	Ranitidine	Gastric/duodenal ulcer and GERD	Ranitidine suspensions 40 mg/ml (25 ml/bottles)	Ranitidine suspensions 10 mg/ml (30 ml/bottles)	Ranitidine powders
	Storage & Stability		Refrigerated 2-8°C, 14 days	Refrigerated 2-8°C, 14 days	90 days
51.	Rifampicin	Tuberculosis	Rifampicin dry syrups 50 mg/ml (30 ml/bottles)	Rifampicin dry syrups 50 mg/ml (30 ml/bottles)	Rifampicin powders
	Storage & Stability		Refrigerated 2-8°C, 30 days	Refrigerated 2-8°C, 30 days	90 days
52.	Sildenafil	Pulmonary hypertension	N/A	Sildenafil suspensions 2 mg/ml (20 ml/bottles)	Sildenafil suspensions 5 mg/ml (20 ml/bottles)
	Storage & Stability		N/A	Refrigerated 2-8°C, 30 days	Refrigerated 2-8°C, 30 days
53.	Spironolactone	Oedema and ascites in cirrhosis of the liver, congestive heart failure	Spironolactone suspensions 10 mg/ml (30 ml/bottle)	Spironolactone suspensions 10 mg/ml (30 ml/bottle)	Spironolactone powders
	Storage & Stability		Refrigerated 2-8°C, 30 days	Refrigerated 2-8°C, 30 days	100 days
54.	Saturated Solution of Potassium Iodide (SSKI)	Expectorant in the symptomatic treatment of chronic pulmonary diseases where tenacious mucus complicates the problem, including bronchial asthma, bronchitis and pulmonary emphysema.	N/A	N/A	SSKI solutions
	Storage & Stability		N/A	N/A	Do not store in a refrigerator 90 days.
55.	Thyroxin	Hypothyrodism	N/A	Thyroxin suspensions 25 mcg/ml (8 ml/bottles)	Thyroxin powders
	Storage & Stability		N/A	Refrigerated 2-8°C, 7 days	90 days
56.	Ursodeoxycholic acid	Gallstone dissolution agent	N/A	Ursodeoxycholic acid Suspensions 20 mg/ml (25 ml/bottles)	Ursodeoxychoolic acid powders
	Storage & Stability		N/A	Refrigerated 2-8°C, 30 days	90 days
57.	Vancomycin	Treatment of infections	Vancomycin eye drops, 50 mg/ml (5 ml/bottles)	Vancomycin eye drops, 50 mg/ml (5 ml/bottles)	Vancomycin eye drops, 50 mg/ml (10 ml/bottle)
	Storage & Stability		Refrigerated 2-8°C, 14 days	Refrigerated 2-8°C, 14 days	Refrigerated 2-8°C, 7 days
58.	Vancomycin	Treatment of infections	Vancomycin, subconjunctival antibiotics 25 mg/0.5 ml (50 mg/ml)	Vancomycin, subconjunctival antibiotics 25 mg/0.5 ml	N/A
	Storage & Stability		N/A	N/A	N/A

Table 3. Examples of the 10 most prescribed medications in various dosage forms based on the formulas provided by three hospitals and other publications.

Drug, dosage form, strength	Procedures	Storage and stability	Comparison with external resources	Study
1. Acetazolamide suspensions 10 mg/ml (50 ml/bottle) Indication: Reduction of intra-ocular pressure in open-angle glaucoma, secondary glaucoma and peri-operatively in angle-closure glaucoma	Two hospitals suggested the following method for the extemporaneous preparation of Acetazolamide: Begin by finely grinding two tablets of 250 mg Acetazolamide in a mortar. Gradually add Vehicle No.1, employing the geometric dilution method in order to achieve a homogeneous mixture. Then bring the mixture up to the final volume of 50 ml with the vehicle.	One hospital recommended dispensing the preparation into an amber glass bottle, sealing it with a cap and label, and storing it in a refrigerator at 2-8°C for 1 week from the date of production. Another hospital advised a similar packaging method but suggested the contents should be stored under the same conditions for up to 30 days from the date of production.	-The storage recommendations for Acetazolamide suspension vary between two hospitals and the Pharmaceutical Service Division of the Ministry of Health Malaysia. The first hospital proposed dispensing the medication into an amber glass bottle and storing it in a refrigerator at 2-8°C, with a shelf life of one week from the date of production. The second hospital also recommends using an amber glass bottle for packaging but extends the storage life to 30 days under refrigeration at the same temperature range. -In contrast, the Pharmaceutical Service Division of the Ministry of Health Malaysia provided a broader storage option for the Acetazolamide suspension at a 25 mg/ml concentration. They suggested refrigeration as the preferred method, but they also consider room temperature storage acceptable. Moreover, they stated that the suspension remains stable for a period of 60 days, which is significantly longer than the storage durations recommended by the two hospitals. -The vehicle of the two hospitals suggested was a vehicle No.1, which prepare by carboxymethyl cellulose (CMC) mucilage, while the Pharmaceutical Service Division of the Ministry of Health Malaysia provide suggested Ora-Sweet®:Oral-Plus® (1:1) or equivalent vehicle. -Allen et al. provided a formulation for acetazolamide at 25 mg/mL, which was prepared using a 1:1 mixture of Ora-Sweet and Ora-Plus, along with a cherry syrup. The mixture was placed in polyethylene terephthalate bottles and stored at 5°C and 25°C for 60 days.	1.The Pharmaceutical Service Division of the Ministry of Health Malaysia (MOH, 2012)[26] 2.Allen et al (1996).[25]
2. Allopurinol suspensions 10 mg/ml (30 ml/bottle) Indication: gout or uric acid and calcium oxalate renal stones	Two hospitals recommended a procedure for preparing an Allopurinol suspension at a concentration of 10 mg/ml in a 30 ml bottle. Begin by crushing three 100 mg Allopurinol tablets into a fine powder using a mortar. Gradually add a small amount of vehicle to the powder, levigating it to create a smooth paste. Continue adding the vehicle gradually to the paste, stirring until a liquid form. Transfer this liquid into a bottle. Use additional vehicle to rinse any remaining drug from the mortar into the bottle. Adjust the volume of the liquid in the bottle to reach the final volume of 30 ml.	Two hospitals suggested storing it in a refrigerator at 2-8°C. The product should be used within 30 days from the date of manufacture.	-The concentrations of allopurinol varied across institutions. Two hospitals provided a 10 mg/ml concentration (30 ml per bottle) for pediatric patients who cannot take tablets, while the Ministry of Health (MOH) and Allen's study provided a 20 mg/ml concentration (120 ml per bottle)."-The vehicle suggested by the two hospitals was Vehicle No. 1, while the MOH and Allen's study suggested Ora-Sweet®: Oral-Plus® (1:1) or an equivalent vehicle. -Two hospitals provided identical storage guidelines for allopurinol suspension, recommending refrigeration at 2-8°C. The product should be used within 30 days. Meanwhile, the MOH suggested refrigerating it at 2-8°C as the preferred option, or alternatively, storing it at room temperature, with the product remaining stable for up to 60 days.	1.The Pharmaceutical Service Division of the Ministry of Health Malaysia (MOH, 2012)[26] 2. Allen et al (1996)[25]

Table 3. Examples of the 10 most prescribed medications in various dosage forms based on the formulas provided by three hospitals and other publications.

Drug, dosage form, strength	Procedures	Storage and stability	Comparison with external resources	Study
3. Aminophylline solutions 10 mg/ml (25 ml/bottle) and 5 mg/ml (50 ml/bottle) Indication: Treatment of neonatal apnea, including post-extubation, post-anesthesia, and prostaglandin E1-induced. Bronchodilator. May improve respiratory function.	Three hospitals proposed protocols for preparing aminophylline solutions from aminophylline injections, with varying concentrations. Two of the hospitals offer a solution concentration of 10 mg/ml in a 25 ml amber bottle. In contrast, the third hospital prepares a solution at 5 mg/ml, doubling the volume to 50 ml per bottle. The preparation process recommended by these hospitals includes drawing 10 ml of aminophylline into a syringe and diluting with sterile water for the injection under a laminar airflow hood. This solution is then passed through a 0.2-micron filter directly into an amber glass bottle to achieve the desired volume.	For storage, two hospitals recommended that the medication should be kept refrigerated at a temperature range of 2-8°C, maintaining its stability for up to 30 days. The third hospital did not provide specific storage information.	-In the study by three hospitals, aminophylline solutions were formulated at concentrations of 10 mg/ml and 5 mg/ml, diluted with sterile Water for Injection, and stored in amber glass bottles following filtration, with a recommended refrigeration period of up to 30 days, though the storage guidelines were not provided by one hospital. Conversely, Chong et al.'s research involved formulating aminophylline solutions at 3 mg/ml and 21 mg/ml using a mixture of Ora-Sweet and Ora-Plus, indicating stability for up to 90 days. However, the 21 mg/ml solution remained stable at room temperature (25°C) over this period, but it failed to maintain at least 90% of its initial concentration after 90 days of refrigeration at 4°C.	Chong et al (2000)[40]
4. Captopril suspensions 1 mg/ml Indication: hypertension	Two hospitals had the same concentration for the captopril suspensions 1 mg/ml (25 ml/bottle) which used vehicle No.1. Another hospital formulated as a powder.	Two hospitals suggested storing it in a refrigerator at 2-8°C for 7 days. Another formulation was suggested storage up to 90 days. formulated as a captopril powders.	-Two hospitals provided identical storage guidelines for captopril suspension, which was a refrigerator at 2-8°C for 7 days. -While the MOH suggested captopril syrup 1 mg/ml and refrigerating it for 30 days. They also provided captopril solution 1 mg/ml and refrigerating it for 56 days. Nahata et al chose to explore the stability of captopril in water and syrup, and additionally included the antioxidant sodium ascorbate in distilled water in their study. With the addition of sodium ascorbate, the shelf life in distilled water increased from 14 days at 4 ºC and 7 days at 22 ºC to 56 days and 14 days, respectively.	1.The Pharmaceutical Service Division of the Ministry of Health Malaysia (MOH, 2012)[26] 2. Nahata et al (1994) [10] 3. Glass et al (2006) [9]
5. Enalapril suspensions 1 mg/ml Indication: Hypertension, Congestive heart failure	All hospitals provided the same formula for the enalapril suspensions 1 mg/ml as follows; 1. Grind enalapril tablets into powder using a mortar and pestle. 2. Gradually mix with vehicle (Vehicle No.3) following geometric proportions until homogenous. 3. Adjust volume to 20 ml.	Three hospitals suggested storing it in a refrigerator at 2-8°C, for 30 days.	-From the MOH extemporaneous formulation, there were two concentrations of the enalapril suspensions: 0.1 mg/ml and 1 mg/ml. The 0.1 mg/ml enalapril suspension used distilled water as a vehicle and was stable for 14 days at room temperature. The 1 mg/ml enalapril suspension used the X-Temp® oral suspension system, which maintained stability for 60 days at room temperature and required protection from light. -Allen et al. suggested that enalapril 1 mg/mL be prepared in a 1:1 mixture of Ora-Sweet®:Ora-Plus®, a 1:1 mixture of Ora-Sweet SF and Ora-Plus, or a cherry syrup, and then stored in 120-mL amber clear polyethylene terephthalate bottles. The preparations, when stored in the dark, were stable for 60 days at both 5 ºC and 25 ºC.	1.The Pharmaceutical Service Division of the Ministry of Health Malaysia (MOH, 2012)[26] 2. Allen et al, 1998.[41]

Table 3. Examples of the 10 most prescribed medications in various dosage forms based on the formulas provided by three hospitals and other publications.

Drug, dosage form, strength	Procedures	Storage and stability	Comparison with external resources	Study
6. Furosemide syrups 2 mg/ml, **Furosemide suspensions** 1 mg/ml Indication: For managing fluid retention associated with heart, kidney, and liver disease, and for controlling high blood pressure, and the treatment of hypertension.	Furosemide syrup, available from two hospitals in 60 ml bottles with a 2 mg/ml concentration. The preparation involves grinding three 40 mg furosemide tablets into a powder with a mortar and pestle and then mixing the powder with a chosen vehicle to achieve a final volume of 60 ml.	Furosemide syrup at a concentration of 2 mg/ml should be stored in sealed, labeled amber glass bottles and refrigerated at 2-8°C; it must be used within seven days. Another hospital's guidelines indicated that furosemide suspension at a concentration of 1 mg/ml remains stable for up to 30 days.	- Thaweethamcharoen et al. supplied a 2 mg/ml syrup of furosemide in a 60 ml PET package with a 30-day expiration period.[42] Preechagoon et al. produced extemporaneous oral suspensions of furosemide (40 mg/60 ml), which were stable for 21 days when protected from light and stored either in a refrigerator or at room temperature.[43]	1.Thaweethamcharoen et al. (2014) [42] 2. Preechagoon et al. (1999) [43]
7. Omeprazole suspensions 2 mg/ml	Two hospitals offer a formulation for omeprazole suspension, provided in 20 ml bottles at a concentration of 2 mg/ml. To prepare the suspension, begin by opening two 20 mg omeprazole capsules and grinding the contents to a fine powder in a mortar. The vehicle used is an 8.4% Sodium bicarbonate solution (pH~8.5) prepared by dissolving 1.68 grams of sodium bicarbonate in distilled water to a total volume of 20 ml. Gradually add this solution to the ground omeprazole in geometric proportions until a homogeneous mixture is achieved. Rinse the mortar with the remaining bicarbonate solution to collect any leftover granules and adjust the total volume to 20 ml. Shake the mixture vigorously to ensure it is well combined.	The prepared suspension should be stored in a sealed, labeled bottle and kept refrigerated at 2-8°C, with a recommended shelf life of 30 days.	The MOH has provided a procedure for the preparation of omeprazole suspension with a strength of 2 mg/mL. To begin, empty the contents of the omeprazole capsules into a mortar. Cover the granules with sodium bicarbonate and stir to mix. Gradually add more sodium bicarbonate until the mixture becomes liquid, then transfer it to a graduated container. Rinse any remaining residue from the mortar with additional sodium bicarbonate solution. The stability of the suspension is up to 14 days when stored at room temperature and up to 30 days if refrigerated. For storage, it is preferable to refrigerate the suspension to prolong its stability, but it can also be kept at room temperature as long as it is protected from light.	1.The Pharmaceutical Service Division of the Ministry of Health Malaysia (MOH, 2012)[26]
8. Phenytoin suspensions 10 mg/ml	Two hospitals had a formulation for phenytoin suspension with a strength of 10 mg/ml in 50 ml bottles. The method involves taking ten 50 mg phenytoin tablets and grinding them to a powder in a mortar and pestle. This powder is then methodically mixed with 50 ml of Vehicle No.1, adhering to geometric proportions to ensure a smooth, homogenous mixture. After the mixture is uniform, the volume is adjusted to precisely 50 ml.	For storage, the suspension is to be kept in a tightly sealed, clearly labeled bottle within a refrigerated cabinet at 2-8°C, maintaining its stability for a period of 30 days.	In the study by Noppawinyoowong et al., a phenytoin oral suspension with a concentration of 10 mg/ml was compounded by triturating 10 Dilantin Infatab™ 50 mg tablets and mixing them with a custom-prepared vehicle totaling 46.5 ml. The vehicle, prepared with water, comprises various ingredients: 0.5% carboxymethylcellulose, 0.1% methyl paraben, 0.02% propyl paraben, 10% glycerin, 10% sorbitol, and 10% propylene glycol, along with 25% syrup. This extemporaneous preparation was shown to remain stable for at least 56 days at room temperature.[44]	Noppawinyoowong et al (2014)[44]
9. Vancomycin eye drops 50 mg/ml	Three hospitals have provided a formulation for vancomycin eye drops at a concentration of 50 mg/ml, utilizing vancomycin powder for injection, 500 mg. The preparation involves dissolving 500 mg of vancomycin in 10 ml of sterile water for injection and then transferring 5 ml of the solution into a container. There is no need for filtration.	One hospital specified that the eye drops should be stored in a refrigerator at 2-8°C for up to 14 days. Another hospital recommended storing the eye drops in a plastic dropper bottle, also in a refrigerator at 2-8°C, but for 7 days.	-Chen et al. have provided a formulation for vancomycin eye drops using an eye wash solution as the diluent, instead of Sterile Water for Injection. They prepared a concentration of 50 mg/mL by reconstituting vancomycin hydrochloride for injection USP, 500 mg, with 10 mL of the eye wash solution. The resulting solutions were dispensed into Steri-Droppers® bottles and stored either in a freezer for 14 days or in a refrigerator for 28 days.[45]	Chen et al. (2020) [45]

Table 3. Examples of the 10 most prescribed medications in various dosage forms based on the formulas provided by three hospitals and other publications.

Drug, dosage form, strength	Procedures	Storage and stability	Comparison with external resources	Study
10. Cefazolin ophthalmic solution	Two hospitals had two concentrations of cefazolin for subconjunctival administration: 200 mg/ml (100 mg/0.5 ml) and another slightly less concentrated at 198 mg/ml (125 mg/0.63 ml). All were formulated by dissolving cefazolin in sterile water for injection and were designed to be used without the need for filtration. These preparations are used for direct administration into the subconjunctival space, offering high local concentrations of the antibiotic. For the eye drops preparation, two hospitals offered cefazolin eye drops at a concentration of 50 mg/ml packaged in 10 ml bottles, which could be stored in the refrigerator or freezer with varying shelf lives, enhancing the versatility of storage options.	For storage, cefazolin eye drops, 50 mg/ml; one hospital recommended that the medication should be kept refrigerated at a temperature range of 2-8°C, maintaining its stability for up to 28 days. Another hospital suggested storing in a refrigerator (2-8°C) for 7 days or storing in a freezer for 30 days.	-Boocharam et al., suggested that cefazolin ophthalmic solution extemporaneous within artificial tears and storage at 4 °C for 28 days. There were different types of preservatives in the artificial tears, for example, benzalkonium chloride or sodium perborate and oxychloro complex. Artificial tears were suggested to as vehicle due to it has appropriate buffer and preservative.	Boocharam T et al. 2014 [36]

Note:
Vehicle No.1: Contains 14 ml of carboxymethyl cellulose (CMC) mucilage, 20 ml of 70% sorbitol, 5 ml of purified water, 1 ml of paraben, 0.18 ml vanilla flavor, and syrup q.s. to 100 ml.

Acetazolamide suspensions

An acetazolamide suspension at a concentration of 10 mg/ml has been documented to reduce intraocular pressure in various forms of glaucoma. Two hospitals delineated a preparation process involving trituration of 250 mg tablets and incorporation with a custom vehicle. Storage recommendations diverge between one week and 30 days when refrigerated at 2-8°C, which is in contrast to the 60-day stability period proposed by the Pharmaceutical Service Division of the Ministry of Health Malaysia. Notably, the vehicle lacked preservatives, aligning with the 30-day storage capability of one facility without preservatives. Further comparison with the literature revealed nuances in the storage and stability criteria. Allen and Erickson (1996) have reported the stability of acetazolamide in compound oral liquids. The Malaysian health division, meanwhile, employs Ora-Sweet® or equivalent vehicles, extending the shelf life under refrigeration conditions.

Aminophylline solutions

Regarding Aminophylline solutions indicated for neonatal apnea and bronchodilation, the hospitals presented protocols for concentrations of 10 and 5 mg/ml. Disparities arose in the storage directives, where two hospitals recommended a 30-day refrigeration period, diverging from Chong et al. (2000), who suggested a 90-day stability for a 3 mg/ml concentration when using a preservative-rich vehicle.

Captopril suspensions

The preparation of captopril suspension, utilized for hypertension, has been harmonized across two facilities with a seven-day refrigerated shelf life, in contrast to a 30-day and 56-day stability period for the syrup and solution forms, respectively, as noted by the Malaysian health authority. This discrepancy raises questions regarding the impact of vehicle preservatives on the longevity of compounded medications.

Enalapril suspensions

Enalapril suspensions for hypertension and heart failure, shared uniformly across all of the hospitals studied, demonstrating a 30-day storage consensus. However, Malaysian guidelines offer 60-day stability for specific suspension concentrations, emphasizing a patient-centric approach to compounding and storage practices.

Vancomycin eye drops

Concluding with vancomycin eye drops, two hospitals employed a formula utilizing injection powder, diverging from Chen et al. (2020), who chose an eye wash solution as a diluent. The storage periods varied significantly: seven to 14 days in hospitals versus 28 days post-freezing.

Cefazolin ophthalmic solutions

These findings, coupled with insights from Boocharam et al. (2014) on the stability of cefazolin ophthalmic solution, highlight the importance of meticulousness in extemporaneous formulations and storage practices. The subtle variations among different healthcare providers reflect adherence to best practices tailored to individual patient needs and the pharmacokinetic properties of the medication.

DISCUSSION

A comprehensive analysis of extemporaneous preparations across three distinct hospitals (A, B, and C) revealed significant differences in hospital structure, staffing, and pharmaceutical capabilities, reflecting broader trends in regional and general

hospital operations within the public health sector. Hospitals A and C were categorized as regional hospitals, whereas Hospital B functioned as a general hospital, each exhibiting diverse bed capacities and scopes of pharmacy services. This diversity highlights the variety of healthcare delivery models prevalent in the public health system and illustrates the unique challenges and opportunities within each facility.

These hospitals offer a range of extemporaneous formulations, from oral liquids to solid dosage forms such as powders and granules, highlighting the essential role of tailored pharmacy services in addressing specific patient needs. The variations in these services reflect the capacities and resources of each hospital, and the demographic and clinical demands they face. For example, the greater variety of oral liquid preparations in Hospitals A and B when compared to Hospital C could be attributed to the larger pediatric population they served, necessitating more pediatric-friendly formulations.

Significant variations in storage and stability practices, particularly in the handling of acetazolamide and aminophylline solutions, emphasize the need for standardized practices and the potential to extend the shelf life of critical medications through optimized compounding techniques and storage conditions. This complexity was further compounded by benchmarks from Allen et al.[25] and the Pharmaceutical Service Division of the Ministry of Health Malaysia[26], illustrating that while hospitals attempted to adhere to established guidelines, local adaptations were often necessary in order to effectively meet specific clinical needs.

The handling of captopril and enalapril suspensions also highlighted discrepancies in the stability periods, which could significantly impact the efficacy and safety of these medications. The observed variations call for ongoing research and the adaptation of compounding guidelines based on empirical stability data and the effectiveness of preservatives.[9]

The discussion on vancomycin eye drops and other formulations, such as cefazolin ophthalmic solution, highlighted an evolving practice in which different diluents and formulations were chosen based on local clinical judgments, storage facilities, and patient populations. These adaptations, while varying significantly across hospitals, are crucial for ensuring patient-specific treatment strategies.[15, 23, 24, 27]

The diversity in preparation forms and storage conditions, such as those for acetazolamide and aminophylline, cater to specific storage requirements and patient demographics, further emphasized by the detailed documentation on stability considerations for liquid dosage forms by Glass et al.[8, 9, 15] This shows that there is a need for more comprehensive research and standardization in the field of extemporaneous compounding. They suggest that future studies should not only expand the scope of the formulations studied but also include more rigorous quality control measures.[9, 28] This would help ensure that all medications meet high safety and efficacy standards, ultimately improving patient outcomes.[15, 24, 29]

The integration of empirical findings from this study with the theoretical frameworks provided by the literature underscores the complex interplay between hospital capabilities, compounding practices, and regulatory adherence in delivering high-quality personalized pharmaceutical care.[4, 23, 30, 31] The need for ongoing education, adherence to compounding standards, and robust quality assurance processes is crucial for enhancing patient outcomes and maintaining trust in hospital pharmacy services.[32, 33] This comprehensive approach is essential for optimizing patient care and underscoring the necessity for collaboration across hospitals to share best practices and develop unified standards, thereby enhancing the overall quality of pharmaceutical care.[32, 33]

The pursuit of standardization of extemporaneous liquid medication formulations is crucial for enhancing patient safety.[23, 24, 34, 35] However, achieving this requires ongoing efforts in evaluation and process improvement. Establishing and consistently applying standard concentrations are the initial steps. Critical follow-up involved evaluating their effectiveness and applicability over time to identify any necessary adjustments. There is a crucial need for comprehensive quality assurance studies on the physical, chemical, and microbiological stability of extemporaneous pharmaceutical preparations.[29, 36, 37] Most hospitals require such studies in order to ensure the safety and effectiveness of these customized medications, particularly for pediatric patients who lack suitable commercial drug options.[24] Research indicates that while pediatric oral extemporaneous formulations generally remain stable under recommended conditions, specific drugs may require unique storage measures to preserve their effectiveness and safety over time.[29]

The importance of stability data for verifying the safety and quality of these medications underscores the need for further in-depth systematic research. Future studies should be expanded to include a wider variety of extemporaneous preparations, focusing on their long-term stability, to guarantee that they safely fulfill therapeutic needs. This should encompass not only routine stability tests, but also monitoring for any physical or microbial changes that might impact drug efficacy and patient safety.[9, 29]

Furthermore, with the growth in the field of extemporaneous compounding, ongoing education and updates on the latest compounding techniques and standards are vital for healthcare providers. Ensuring that all personnel are well trained to produce high-quality, consistent medications tailored to patient needs is essential. By enhancing collaboration and sharing best practices among hospitals can also significantly improve the standardization and quality of these crucial services.[8, 38]

Although this study provides valuable insights into the practices of extemporaneous compounding across three distinct hospitals, some limitations must be acknowledged in order to accurately contextualize the findings. First, the scope was limited to three hospitals, which may not represent the full diversity of hospital settings and practices nationwide or globally. While providing a rich comparative analysis, the specific characteristics of these hospitals, such as their regional or general classification and varying bed capacities, also limited the generalizability of the results to other settings. Another

limitation was the reliance on available data regarding the storage and stability of medications. The data collected were dependent on the records and practices of individual hospitals, which might not have captured all the nuances or variations in practice, particularly with less common formulations. Furthermore, the observational nature of the study means that causal relationships between hospital practices and patient outcomes could not be firmly established.

Further research should explore several avenues in order to enhance the understanding and application of extemporaneous compounding in hospital settings. Future studies should expand the sample size to include a more diverse array of hospitals, including those in rural or underserved areas, to examine how different resources impact compounding practices. Longitudinal studies can also be conducted to track the long-term stability and efficacy of extemporaneous formulations to provide a more dynamic view of their performance over time.[39]

In addition, it would be beneficial to integrate more robust quality control measures into the study of extemporaneous formulations. This could involve advanced chemical analysis to confirm the stability and consistency of compound medications as well as controlled trials for direct measurement. Research could also explore the impact of specific training programs for pharmacy staff on the quality and safety of extemporaneous preparations by assessing whether targeted education can reduce discrepancies in practice and improve patient outcomes.[4]

Finally, a collaborative research initiative across hospitals should be established to share data and best practices, thereby fostering a more standardized approach to extemporaneous compounding. Such collaborations could lead to the development of shared guidelines and protocols that leverage collective experiences and data to enhance patient care on a broader scale. This collaborative approach could also explore the use of new technologies and techniques in regard to compounding to further advance the field.[18, 24] In summary, although this study laid a foundational understanding of current practices in extemporaneous compounding across the selected hospitals, future research is essential to broaden these insights and refine practices to ensure the highest standards of patient care and medication safety.

CONCLUSION

This study provides a detailed comparison of extemporaneous pharmaceutical practices across three distinct hospitals, revealing considerable differences in their structures, staffing, and capabilities within regional and general hospital settings. These differences reflect diverse healthcare delivery models and specialized approaches necessary to meet specific patient demands. These findings underscore the importance of extemporaneous formulations in providing patient-centered care, particularly for pediatric patients, by offering a range of medications suited to their needs. Stability considerations are crucial because proper formulation and storage conditions are vital for the prevention of medication degradation and ensuring safety. In conclusion, the integration of these findings with those of existing studies illustrates the complex relationship among hospital operations, pharmaceutical practices, and regulatory standards, highlighting the need for an integrated approach to pharmaceutical care. Future research should expand on these findings and promote standardized practices and collaboration across hospitals to enhance the quality of care and patient safety of pharmaceutical services.

CONFLICTS OF INTEREST:

None.

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