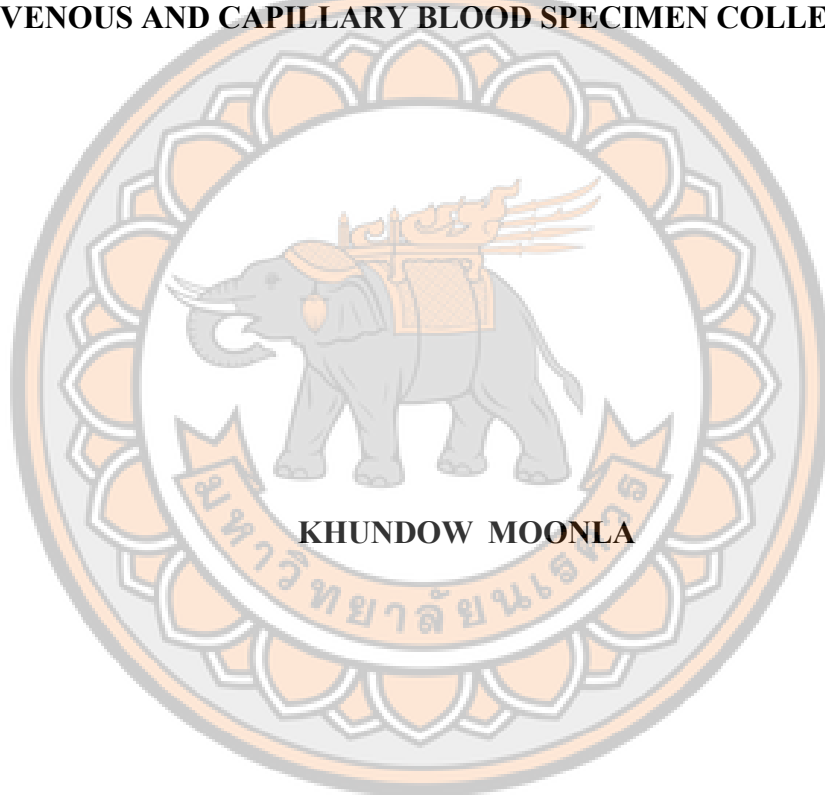




**CLINICAL EVALUATION OF INNOMED VACUUM TUBES ACCORDING
TO CLSI GP34-A VALIDATION AND VERIFICATION OF TUBES FOR
VENOUS AND CAPILLARY BLOOD SPECIMEN COLLECTION**



**A Thesis Submitted to the Graduate School of Naresuan University
in Partial Fulfillment of the Requirements
for the Master of Sciences in Biomedical Sciences**

2025

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Thesis entitled " Clinical evaluation of innomed vacuum blood collection tubes based
on GP34-A validation and verification"

by Khundow Moonla

has been approved by the Graduate School as partial fulfillment of the requirements
for the Master of Science in Biomedical Sciences of Naresuan University

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ABSTRACT

Blood collection tubes (BCTs) are critical in vitro diagnostic devices used in clinical laboratory testing. Innomed tubes are novel BCTs coated with heparin and anti-glycolytic agents (Innomed 1) and clot activators combined with anti-glycolytic agents (Innomed 2). This study, we focus on the verification and multicenter validation of Innomed tubes. Two types of Innomed tubes were evaluated. The verification process, conducted in a reference laboratory, assessed biochemical interferences, glucose stability, and the potential for hemolysis due to centrifugation and blood collection techniques. The multicenter validation of biochemical interferences was carried out across five hospital laboratories. Glucose levels in Innomed 1 and 2 remained stable within 8% of up to 8 h post-collection. No hemolysis was observed under varying centrifugation times (at 3,500 rpm) and blood collection techniques, as confirmed through visual inspection and lactate dehydrogenase level determinations. Innomed tubes were suitable BCTs for glucose, HbA1c, thyroid stimulating hormone, free triiodothyronine, free thyroxine, triiodothyronine, carcinoembryonic antigen, and prostate-specific antigen, as well as for 19 routine biochemical assays. Innomed 1 and 2 BCTs maintain blood glucose stability for 8 hours, ensuring accurate biochemical, HbA1c, thyroid, and tumor marker testing. Their hemolysis resistance supports diabetes screening and NCD monitoring.

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CHAPTER I

INTRODUCTION

Background and state of problems

A clinical laboratory is a laboratory where tests are done on clinical specimens in order to get information about the health of a patient as pertaining to the diagnosis, treatment, and prevention of disease [1]. Examination of biochemical substances in venous blood is the most popular laboratory-based specimen testing method. Chemical methods were employed to consider pathological changes in tissues and organs according to their normal functions. When an abnormality or disease happens, these processes will lead to in-cell changes, and biochemical substances in the cells will enter the blood stream. Testing biochemical substance changes in blood enable us to realize organ aberration [2] At present, laboratory testing includes blood collection of all types, and blood tubes coated with various anticoagulants are used. As a result, multiple blood tubes for specimen collection are used at once, and a patient's blood must be collected in large quantities [3].

The most common biochemical test is glucose. For blood specimen collection, sodium fluoride (NaF) tubes are commonly used. The error in glucose results can lead to missed diabetes diagnosis, monitoring, and treatment (DM). When used in large quantities, sodium fluoride acts as an anticoagulant and an anti-glycolysis agent by inhibiting enolase in the glycolysis pathway [4]. The disadvantages of NaF are that it takes up to 4 hours to completely inhibit hemolysis [5]. To avoid hemolysis, sodium fluoride is frequently combined with other anticoagulants. To address the issue of delayed fluoride activity, blood collection tubes coated with a substance containing citrate buffer and NaF-EDTA were introduced [6]. However, because the glucose concentration in this tube is significantly higher than in the NaF tube, it is not widely used [7]. A heparin tube is a tube that has been coated with heparin. The most common form is heparin with lithium salt. The heparinized plasma can be separated immediately, which speeds up the specimen preparation process. An excessive dose of heparin can cause hemolysis, interfere with light absorption, and result in incorrect analysis results. Furthermore, red cell rupture can increase intracellular substances in the bloodstream

such as phosphate and lactate dehydrogenase [8]. A blood collection tube coated with the appropriate amount of heparin can be used to collect blood samples for routine biochemical tests such as glucose[9,10]. However, because heparin is not an anti-glycolysis agent, glucose decreases by 10 mg/dL per hour at 25°C when the pre-analytical process is delayed [11].

Blood collection tubes are IVD (In Vitro Diagnostic) medical devices for external diagnosis that must be manufactured by an FDA-certified medical device facility in order to meet ISO 13485 medical device standards. Medical devices – Quality management systems – regulatory requirements [12]. WE Med Lab Center Co., Ltd. manufactures innomed tubes. These tubes are unique in that they are coated with the right amount of anticoagulants (formula 1), clot activators (formula 2), and anti-glycolysis agents.

The goals of this research are to obtain clinical data from laboratory test comparisons using blood samples from Innomed tube versus reference tubes, as well as to ensure that the performance of Innomed tube is used in accordance with international standard guidelines.

Purposes of the Study

- 1.To investigate the effects of the anti-coagulant-coated in Innomed tube by comparing with to references tubes.
- 2.To evaluate the impact of the centrifugation time to biochemical test result values.
- 3.To assess the effects of blood collection techniques to biochemical test result values.
- 4.To determine hemolysis levels at different storage times.
5. To validate blood collection tubes by users from multicenter studies, modify the CLSI GP34-A validation and verification of tubes for venous and capillary blood specimen collection guidelines.

Research significance

The life cycle of IVD medical devices includes design and development, verification and validation, transfer, production, and post-marketing, as blood collection tubes are medical devices. Validation is required by the market to ensure its validity, as well as to ensure that the blood collection tube meets the criteria for its intended use, as well as the test results, which serve as proof of the product's usability.

The findings will aid in the development of confidence in those who use blood collection tubes. When the product is first introduced or sold, it is used for validation by hospitals, clinical laboratories, and mobile health examinations. This has consequences and issues, such as an incorrect analysis result because the blood sample was taken in a non-validated blood collection tube, causing the laboratory to report an incorrect result to the physician. This leads to misdiagnosis by physicians, who then fail to properly treat the patient or administer drugs that are ineffective for the treatment.

Scope and limitations of the study

In this study, clinical evaluations of Innomed tubes were performed, which are manufactured by We Med Lab Center Co, Ltd. and whose manufacturing process is ISO 13485 certified. A comparison of eight biochemical analytes (glucose, total cholesterol, BUN, creatinine, uric acid, ALT, total protein, LDH), a complete blood count (CBC), Hemoglobin A1C (HbA1C), and thyroid hormones is included in the clinical evaluations (TSH). The first four studies were conducted at Naresuan University's Medical Device Research Laboratory, and the fifth at participating hospitals that have tested Innomed tubes. The study will follow CLSI GP34-A validation and verification of tubes for venous and capillary blood specimen collection.

Term and definition

1. Verification: Confirmation through review and there is evidence that it meets the specified requirements [13].
2. Validation: Activities or processes to prove that the test procedure, test process, test system, device, or test method used can be used for its intended purpose[13].

3. Clinical evaluation: The assessment and analysis of clinical data related to a blood collection tube product. To determine the medical safety and effectiveness of blood collection tubes when used as intended, as determined by the medical device manufacturer [13].

4. Multi-center studies: A project that tries to research but has only one research study. Including hospitals participating in the blood collection tube efficiency test.

5. Innomed tube: Blood collection tubes coated with lithium heparin and anti-glycolysis agents (formula1) and blood collection tubes coated with clot activator and anti-glycolysis agents.(formula 2) are a vacuum blood collection tubes.

6. Formula 1: Blood collection tubes coated with lithium heparin and anti-glycolysis agents.

7. Formula 2: Blood collection tubes coated with clot activator and anti-glycolysis agents.

8. Commercial tubes: Blood collection tubes that are commercially available. The reference tubes in this study were Greiner Bio-One brand blood collection tubes.

9. Reference tubes: Tubes used in general hospitals Z tube, heparin tube, clot activator, NaF and EDTA

10.Z-tubes: Glass blood collection tubes that are not coated with any substance.

Preliminary agreement

1. Blood samples are venous blood specimens collected from healthy and diseased subjects who volunteer to participate in this research project.

2. International standard guidelines include CLSI GP34-A validation and verification of tubes for venous and capillary blood specimen collection guidelines.

3. Multi-center studies were followed work instructions by modifying CLSI GP34-A validation and verification of tubes for venous and capillary blood specimen collection guidelines.

4. Innomed tubes coated with anticoagulants (formula 1) or clot activators (formula 2) and anti-glycolysis agent that was produced by WE Med Lab Center Co., Ltd. The production process has been certified by ISO 13485.

Hypothesis

Blood collection tubes with Innomed tube vacuum. According to the CLSI GP34-A validation and verification of tubes for venous and capillary blood specimen collection guidelines, that were coated inside with clot activator or heparin and anti-glycolysis agents are acceptable.



CHAPTER II

LITERATURE REVIEW

Clinical laboratory testing [1,2]

laboratory tests obtained from the clinical laboratory are used to indicate abnormalities in physiological processes. The lab results usually show a change in the concentration or value of testing that is higher or lower than normal. Only if the laboratory result is accurate and reliable can it be used in disease diagnosis, treatment, monitoring, and prevention. The physiological and biochemical processes that occur in the bodies of healthy and sick people are used to interpret the diagnosis.

Blood specimen collections [14]

Blood is the most commonly used specimen in clinical laboratories for measurements, particularly in clinical chemistry testing. A centrifuge separates the cellular portion of the blood specimen from the lymph portion, serum, or plasma. The serum portion is obtained by allowing the blood to clot naturally without the use of an anticoagulant. For 30-45 minutes, the blood is usually clotted. The total time from blood collection to serum availability for measurement is about one hour. Several types of anticoagulants are used to collect blood specimens, depending on the test and intended use.

Blood additive agents for blood collection tube

Heparin is a thrombin-neutralized substance that inhibits the plasma reaction. The antithrombin II factor in the blood clotting process prevents the conversion of fibrinogen into fibrin, and the general ratio that uses heparin 0.1-0.2 mg per 1 ml of blood. This anticoagulant is used to measure osmotic fragility, hematocrit, and ESR, but it is not suitable for blood smears because it turns the background green and interferes with leukocyte counting [8,10,16].

Sodium fluoride is an anticoagulant that can be used to collect blood samples in order to determine blood glucose levels. Blood glucose cannot be used for blood clotting because it inhibits the enzyme enolase in glycolysis (glycolysis). Blood glucose levels drop by about 10 mg/dL/h when sodium fluoride is not used as an anticoagulant. Sodium fluoride has the advantage of being inexpensive, but it also has the disadvantage of frequently causing hemolysis and interfering with the glycolysis process [11].

K2 Ethylene diamine tetraacetic acid tube (EDTA) is a popular substance. As many blood clots have hematological, the EDTA can use with both disodium salt and dipotassium salt, but dipotassium salt is the better watermark. Currently, EDTA anticoagulants in vacuum tubes. The principle is that EDTA is the chelating effect of calcium in the help, with calcium bound to calcium, prevent blood clotting. The disadvantage of EDTA is that it can maintain the size of blood for a long time, but if it is used too much, it is 1.5 ± 0.25 mg per 1 ml of blood, causing red blood cells to atrophy, resulting in a decrease in cell packing volume (PCV), when more than 2 ml per 1 ml of blood cause a significant decrease in PCV and MCHC levels. Citrate

solution is a citrate substance that binds to calcium as citrate prevents the hardening of blood [14,16] .

Oxalate has the calcium oxalate properties that prevent it. Double oxalate is made by combining ammonium oxalate and potassium oxalate in the proper proportions to prevent red blood cells from deforming. The rate of red blood cell precipitation, the amount of hemoglobin, but not suitable for blood smear because it changes the shape of leukocytes, is vacuole and nucleate in the form of nuts. It is not very popular right now [15].

Citrate solution, in the form of disodium citrate prepared as 3.8 percent sodium citrate, is used to test blood clotting factors and red blood excretion rate in a sodium citrate ratio of 1 ml per 9 ml of blood (ESR). Acid citrate dextrose solution (ACD) is used for blood collection so that the patient's blood or a blood transfusion containing dextrose can nourish and maintain red blood cells, allowing them to last longer. However, it is uncommon to examine the shape of red blood cells [15,16].

Clot activator plain tubes are the standard tubes used to collect blood samples for most analyses. The fibrin clot, however, must clot for at least 30 minutes before serum can be obtained. The time it takes to complete each step of the laboratory process, from sample preparation to reporting, is a measure of laboratory efficiency that has a significant impact on patient care. The inability of the laboratory to perform the test has an immediate effect on the analytical results. The glycolysis process, in particular, causes a rapid drop in glucose levels [15].

Therefore, plasma samples are used in some laboratories for urgent testing. Plasma, however, cannot be used in place of serum because fibrinogen and other clotting factors have a higher viscosity and total protein content than serum. It may contain platelet and cellular impurities, which can skew test results. As an alternative to serum from non-anticoagulant tubes, blood collection tubes with clot activator coating are now available [17].



Figure 1. Type of blood collection tubes

Table 1 The previous studies of blood additives and the effect on biochemical analysis in clinical chemistry testing.

Agents	Using	Glucose Stability	Advantage	Disadvantage
Glyceraldehyde (GA) [18]	Combination of GA, NaF and K-oxalate	48 h	No hemolysis	- Fresh preparation
Glyceraldehyde (GA) [19]	10 mmol/L	8 h	- No effect either glucose oxidase or Hexokinase method - Electrolyte	- Fresh Preparation - Increase Creatinine (alk. picrate method) - AST decreased
D-mannose [20]	Combination of D-Mannose (3 g/L) and NaF (6 g/L)	-15 min: increased -After 15 min: slowly decreased	No hemolysis	- positive interfere with glucose oxidase method - negative interfere with Hexokinase method - Unsuitable for electrolyte (Na, K)
D-mannose [21]	Combination of D-Mannose (3 mg/mL) and Heparin	- After 3 h decreased < 1%	No hemolysis	Interfere potassium and Creatine kinase
Sodium Fluoride [22]	8-20 mg/dl (1 % NaF + 0.2 % oxalate)	3 day	Maintain glucose for long time	Hemolysis Delayed for up to 4 hours
Citrate buffer [23]	Combination of citrate buffer NaF and EDTA	After 2 h decreased 0.3 % and After 24 h decreased 1.2 %	-	-
Citrate buffer [24]	Combination of citrate buffer NaF and EDTA	96 h (4 day) At room temperature	- Maintain glucose for long time - No decrease of glucose concentration demonstrated throughout the study period (0-96 h)	No data

Renu Wiriyaprasit (2010) [25] discovered that blood supplements or solutions containing heparin-type anticoagulants, lithium salts, and glucose-containing anticoagulants (antiglycolytic) glyceraldehyde and D-mannose in appropriate proportions can be used in medical laboratories to collect blood samples for biochemical analysis. Because it contains other antiglycolytic inhibitors, this infusion has advantages over the current lithium heparin anticoagulant. It can also keep blood glucose levels stable for up to 8 hours.

Data from a research project on mixtures that prevent blood cells from using glucose. Assistant Professor Wanvisa Treebuphachatsakul, Ph.D., has filed for two petty patents, titled "Mixtures for increasing the efficiency of blood glucose treatment and for biochemical analysis in medical laboratories" (Thai Petty Patent No. 6620. September 26, 2011). Heparin and glyceraldehyde make up the mixture. Glycerin and "Mixtures for Use as Anticoagulants and Glucose Inhibitors in Clinical Chemistry Laboratory Biochemical Analysis" (Thai Petty Patent No. 6622. 26 September 2011) [26,27], a glyceraldehyde, D-mannose, and heparin mixture can be coated in the appropriate ratio blood collection tubes and found to maintain the sugar level for 8-16 hours.

Walunporn Ungsawat (2016) [28] investigated the "Innotube," a blood filler containing the anticoagulant lithium heparin. To measure glucose, the anti-glucose degradation agents glyceraldehyde and D-mannose were used. In five participating hospitals, biochemical and hematopoietic values can be used to analyze 15 biochemical substances and the completeness of 13 blood cells. Blood cannot be collected using Innotube tubes for platelet count analysis.

Therefore, education is necessary. Determine the appropriate dosage and composition of the clot activator. In addition to both the type and dosage for intravesical coatings in blood collection tubes. So that these substances can act properly. Without compromising the quality of the blood sample and the results of the analysis.

Glycolysis pathway [29]

The main source of energy for red blood cells is glucose. Anaerobic glycolysis converts approximately 90% of glucose to pyruvate or lactate. Energy is released in the form of ATP and NADH as the end product. The energy generated is used to keep the cells healthy. Maintaining the biconcave state of red blood cells as well as the level of intracellular electrolytes. Glycolysis is the breakdown of glucose through a series of reactions or processes. Pyruvic acid, a compound with two molecules of three carbon atoms, is formed by starting with glucose, a compound with six carbon atoms. There are ten steps in total, each with a different enzyme acting as the catalyst. The glycolysis pathway is made up of ten enzymes. This glycolysis pathway was studied by Embden, Meyerhof, and Pranas, hence the name. Embden-Meyerhof Pathway all glycolysis pathways take place in the cytosol, which can be found in cells from all body tissues. Embden, Meyerhof, and pranas studied this glycolysis pathway, hence the name. Pathway between Embden and Meyerhof .

In this research, the Innomed tube is combined with an anti-glycolysis agent that inhibits hexokinase, the first enzyme in the glycolysis process. It is more effective than sodium fluoride, which inhibits enolase, the ninth enzyme in the glycolysis process.

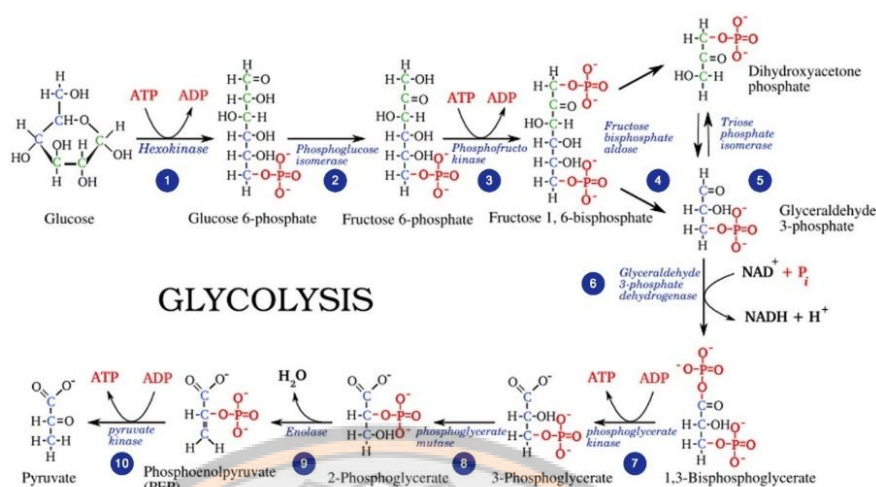


Figure 2 Glycolytic pathway

[30]

The most common method is intravenous blood collection because it can be used to obtain enough blood for a variety of tests. Torn to prevent blood vessel rupture, causing blood to leak from beneath the skin until swelling occurs green and dark. Currently, blood collection tubes are made of vacuum tubes, which work on the principle of pressurizing blood into vacuum tubes, without the need to draw blood.



Figure 3 Venous blood collection from the arm

Blood biochemical analysis is one example of a laboratory test. Each test, such as a blood glucose measurement or a complete blood test, necessitates a different blood collection tube. As a result, a blood sample is required. Furthermore, a certain volume of blood must be collected, according to the specified proportion of the blood collection tube type, as a result, intravenous puncture necessitates large amounts of blood, ranging from 10 to 15 ml each time [31].

Hemolysis

Hemolysis can occur both in and out of the body. In vivo hemolysis can also be caused by a disease process that destroys intravascular erythrocytes. Repeated blood collection and continued receipt of hemolysis specimens frequently indicate intravascular hemolysis and should alert the physician. Hemolysis can occur as a result of difficult venipuncture or improper specimen handling. When blood is drawn from a catheter with connectors with extremely small or large internal diameters, hemolysis can occur. Internal diameter changes can cause turbulence and cell disruption, resulting in hemolysis. When the specimen is hemolysis in vitro, certain tests were inaccurate [32].

Hemolysis interferes with routine biochemistry parameter assays, resulting in higher than biochemical values for LDH, AST, and potassium. and discovered that it interferes with the measurement of total bilirubin, resulting in a lower value than the actual value. shown in the graph as shown in Figure 4. [33]

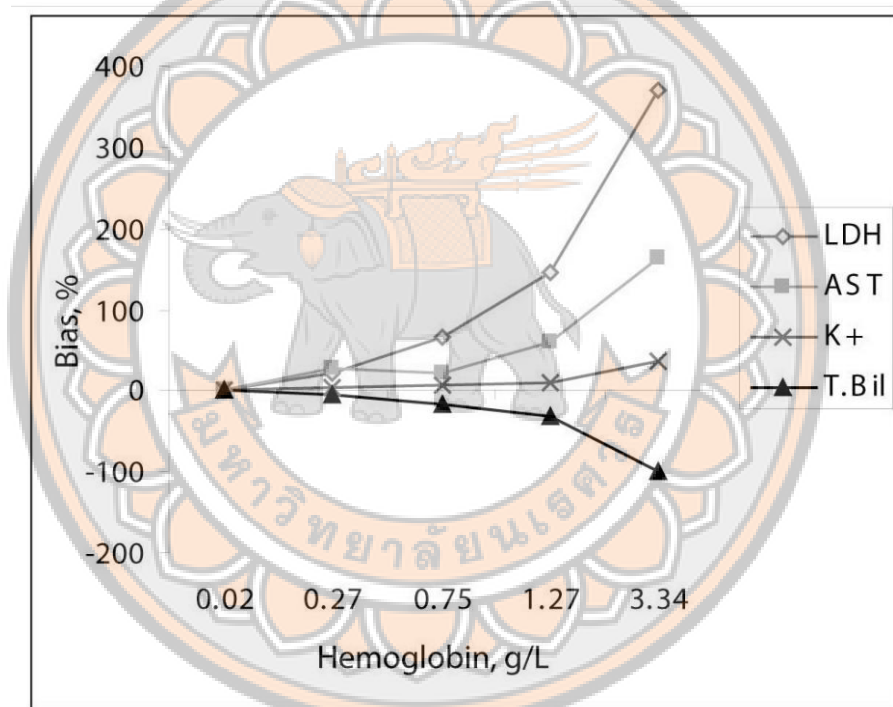


Figure 4 Interferogram for hemoglobin and measured parameters: LD, AST, potassium and total bilirubin.

Principles of glucose determinations [34]

The glucose hexokinase principle. Enzymes attach glucose to the phosphate group. In the presence of ATP (adenosine triphosphate) and magnesium ions, hexokinase (HK) converts glucose-6-phosphate and ADP (adenosine diphosphate). Glucose-6-phosphate dehydrogenase (G6P-DH) converts NAD⁺ to NADH by oxidizing glucose-6-phosphate. The absorbance is measured at 340 nm and is proportional to the concentration of glucose in the sample.

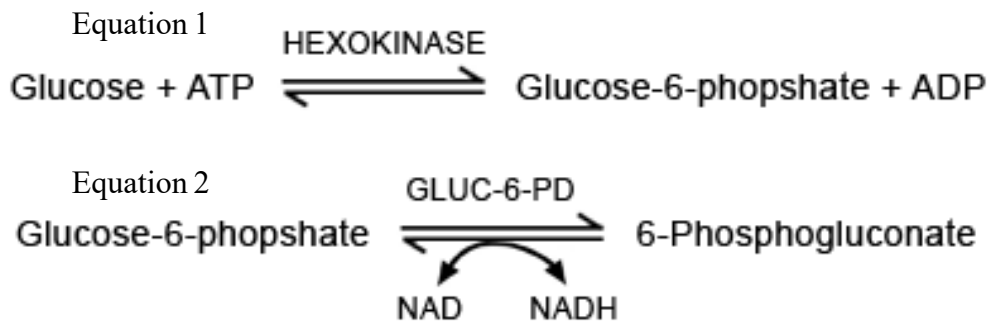


Figure 5 Principles of glucose analysis

The standard is related to the quality of blood collection tubes.

ISO 13485 Medical devices - Quality management systems - Requirements for regulatory

Design and development plan [12]

The requirements for design and development of medical devices shall be defined in the process of manufacturing medical devices in accordance with ISO 13485 Medical devices - Quality management systems - Requirements for regulatory purposes section 7.3: a) functional, performance, usability, and safety requirements based on intended use; b) applicable regulatory requirements and standards; c) applicable risk management output(s); d) as appropriate, information derived from previous similar designs; e) other requirements essential for the product's design and development and processes. These inputs must be reviewed for appropriateness and approval.

Design validation is the final step in the design and development of a medical device before it is transferred to the next step. Clinical evaluation is the methodological study of design validation. medical device clinical data collection, evaluation, and analysis Examine whether the available medical evidence is sufficient to confirm the medical device's critical safety and efficacy requirements. When using a medical device in accordance with the manufacturer's instructions.

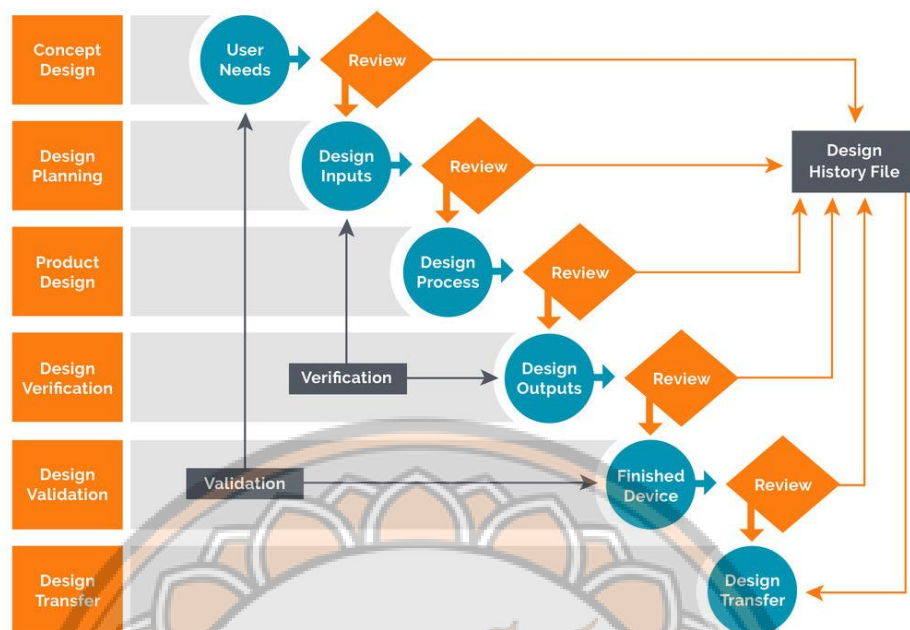


Figure 6 Design and development plan medical device

CE Marking [35]

Medical devices are classified according to the risk (risk classification) they pose to users and patients under the conditions. As a result, the Medical Devices Act requires that medical information be evaluated. This is required in order to confirm the effectiveness and safety of medical devices.

Medical devices in accordance with the MEDDEV Guidelines 2.7.1 Medical devices must be tested in the field, or medical information on the use of the device to the patient of the medical device. The clinical evaluation shall be conducted in accordance with the Medical Device Regulation (MDR 2017/745), IVD 98/79/EC, or CE labeling that requires clinical testing or evaluation (Article 61) for a highly effective medical device. risk Clinical testing must be and performed in accordance with ISO 14155.

Clinical Evaluation [35]

A methodologically sound ongoing procedure to collect, appraise and analyze clinical data pertaining to a medical device and to evaluate whether there is sufficient clinical evidence to confirm compliance with relevant essential requirements for safety and performance when using the device according to the manufacturer's instructions for use. In MEDDEV 2.7.1, the assessment process is divided into 5 stages:

Stage 0: Determination of the scope of the clinical evaluation and preparation of a plan), which defines the scope, purpose and description of the medical device. Summary of product comparisons (device equivalence) in all 3 domains: Biological/Technical/Clinical Establish roles, tasks, and qualifications of assessors.

Stage 1: Identify data to be evaluated and strategy for literature search. Identify clinical data sources Must be a reliable source and related to the product The

most popular data sources are MEDLINE, PUBMED Define methods or strategies to collect consistent data. and match the defined scope and objectives

Stage 2: Assess relevant data and summarize data sets. Evaluate the quality of the research or bibliography (literature) collected Can be evaluated qualitatively or quantitatively collected.

Stage, 3:, Conduct analysis of data to see if it meets requirements Analyze the results of clinical research or a bibliography to determine and collect the safety and effectiveness of a medical drug. Benefit-risk-benefit-risk review of the medical device manual (instructions for use).

Step 4: Compile the clinical evaluation report (CER). Develop a report from stages 1 - 3. Develop a plan for post-market surveillance (PMS). Post-market clinical follow-up (PMCF) plan and vigilance system.

ISO 6710:2017 Single-use containers for human venous blood specimen collection [36]

Is the industry standard for disposable containers used to collect human venous blood specimens. The following are the topics: - Materials by inspecting the transparency of the inside of the tube. UV light exposure or exposure to the range of light normally seen by the eye There is no deterioration.

- The label and container indicate the maximum ingredient/substance content. Inside the blood collection tube - According to the criteria, the volume of blood in the tube (draw volume) tested according to the prescribed method for vacuum blood collection tubes (Annex B: Draw volume test) is within 10% of the filled volume.

- The shape (design) of the closure is tested by examining its appearance in relation to the specified criteria, i.e. not loose or slack during blood mixing and leakage. By conducting tests in accordance with Appendix C (Annex C: Container Leakage Test), no leakage of the fluorescent agent into water is detected. The stopper can be removed with your finger or a special tool. The sample may come into contact with parts of the cap. and ensure that it can be used with automated analyzers as well as for movement in the transport system applications in pre-analytical processes process during analysis.

- construction as determined by the tube durability test (Appendix D: Container Robustness Test) when centrifuged at 3,000 g or as specified by the manufacturer. Look for noticeable characteristics such as no cracks, no leaks, no sharp edges, and no bulging or rough surface. This may result in an accident, cuts, or lacerations on the user's skin. - The specified amount of additive, with the amount of each specified blood additive falling within the specified range and ratio (Annex E: Examination. Check the concentration and volume of blood additives used: additive concentration and volume of liquid additive). The mixing procedure for blood collection tubes with containers (containers with additive) must be indicated by shaking, according to the criteria. Other physical methods of foaming or mixing the blood are not permitted.

- Visual inspection for marking and labeling Examine the package label's features, such as symbols, labeling, and shelf life. Unopened tubes with the appropriate letter code and/or product name or symbol format are sterile and labeled "single use only" or symbol. Include information on the package or in the documentation that

comes with it. including use under specific conditions clearly stated on the blood collection tube, label, and/or datasheet

- Verify the information on the label that identifies the container using the recommended color code for blood additive and equipment labeling (Annex F: Review of product labeling and tube color). Blood and Supplies recommended color codes for identifying blood additives and supplies), which include letters indicating the type of blood additive and other components, as well as the color of the tube cap.

Verification and Verification of Venous Blood Collection Tubes [13]

The Institute of Laboratory Sciences and Medicine (CLSI) published guideline GP-34A in 2010 with the goal of providing procedural details for the verification and verification of blood collection tubes. This guideline focuses on the verification of blood collection tubes from the standpoint of the manufacturer. This ensures that the design and performance meet the requirements. Specimen Collection). Verification and verification of tubes for venous and capillary blood. Statistical testing is effective when there are between 20 and 100 people .

1. selection of samples Take part as a volunteer. The sample should include an equal number of males and females aged 18 and up. In other words, healthy and Patient samples.

2. Select the detected test in the routine. As a result, the study chose articles with laboratory tests that show frequent remissions.

3. Take note of the observed features such as serum/plasma, fibrin, and hemolysis.

4. Choose dependable test instruments and methods.

5. When testing parameters, consider repeat testing.

Analysis of the data [13]

Among the research results, the significance of the evaluation should demonstrate that the use of the innomed tube has an acceptable operational use. The use of innomed tubes does not increase the error and combination of bias and inaccuracy, nor does it reduce the effectiveness of blood collection tube measurements.

To assess the consistency of the results after completing the evaluation of the new blood collection tube Check for deviations in each production model and the impact of deviations from the manufacturer's recommendations in the tube manufacturing process. In addition to monitoring programs for changes in subsequent production generations, records must be kept in a logical (numerical) format to allow for both qualitative and statistical data planning and evaluation for data availability. can be correlated linearly The ranges are evenly distributed and are also compared to the data validation results. Several statistical methods can be used to estimate the expected bias and its confidence interval.

Statistical analyses [13,37]

Method for analyzing trueness Comparison of test tube results with reference test tubes.

Evaluated with %Bias < Bias_d value and/or P-value > 0.05, 0.017 of Paired t-test

Bias = difference between test tubes and reference tubes

$$\text{Bias (\%)} = \frac{(\text{test tube} - \text{reference tube})}{\text{reference tube}} \times 100$$

Bias_d is the difference in effect on clinical treatment. It is used in accordance with the desirable bias (link Desirable Biological Variation Database specifications - Westgard).

Clinical acceptance criteria [13]

Should not base your decision solely on statistical significance. There are times when significance is established despite the absence of clinical significance. A possible clinically significant difference, on the other hand, may not be statistically significant. Clinical acceptance criteria are used to determine whether a tube's performance is suitable for use in a clinical setting. This performance can be assessed by setting acceptance limits for test results that are likely to be considered clinically equivalent. The laboratory staff or clinicians at each facility, in collaboration with the medical staff or literature, determine these acceptance limits. Acceptance criteria examples include evaluation of data using the formula for the imprecision of replicates biological variation for a measurand and published data.

CHAPTER III

RESEARCH METHODOLOGY

This study is applied research and under the human ethics certification IRB No P3-0093/2564 by Naresuan University institutional review board.

Innomed blood collection tubes formula 1 and formula 2 were produced and passed the standard for post-production quality control and physical testing according to ISO 6710: Single-use containers for human venous blood specimen collection. Both formula blood collection tubes were used for clinical evaluation in accordance with CLSI-GP34-A (Validation and Verification of Tubes for Venous and Capillary Blood Specimen Collection) by the Medical Device Research Laboratory which has been certified by ISO15189/15190, Naresuan University

Both formulas of blood collection tubes were used to collect venous blood samples in 12 healthy volunteers and 24 patients with diabetes or NCD (n=36), and equal numbers of males and females in each group. Each sample were measured the level of glucose and biochemical analytes by automated analyzers which cover the following measurements

Innomed Blood Collection Tube (Formula 1)

1. Biochemical analytes (15 parameters)

- 1.1 Glucose (GLU)
- 1.2 Albumin (ALB)
- 1.3 Alkaline phosphatase (ALP)
- 1.4 Alanine aminotransferase (ALT)
- 1.5 Aspartate aminotransferase (AST)
- 1.6 Direct bilirubin (DBIL)
- 1.7 Total bilirubin (TBIL)
- 1.7 Blood Urea Nitrogen (BUN)
- 1.8 Cholesterol (CHOL)
- 1.9 Creatinine(CRE)
- 1.10 HDL-Cholesterol (HDL)
- 1.11 Lactate dehydrogenase (LDH)
- 1.12 LDL-Cholesterol (LDL)
- 1.13 Total Protein (TP)
- 1.14 Triglyceride (TG)
- 1.15 Urine analysis (UA)

2. Complete blood count (CBC)

- 2.1 White Blood Cell (WBC)
- 2.2 Red Blood Cell (RBC)
- 2.3 Hematocrit (HCT)
- 2.4 Mean Corpuscular Volume (MCV)
- 2.5 Mean Corpuscular Width (MCH)
- 2.6 Platelet (PLT)

- 2.7 Neutrophil (NEU)
- 2.7 Lymphocyte (LYM)
- 2.8 Monocyte (MON)
- 2.9 Eosinophil (EOS)
- 2.10 Basophil (BAS)

3. Hemoglobin A1C (HbA1c)

4. Thyroid hormone

- 4.1 Thyroid-stimulating hormone (TSH)

5. Cancer markers

- 5.1 Carcinoembryonic antigen (CEA)

Innomed Blood Collection Tube (Formula 2)

1. Biochemical analytes (15 parameters)

- 1.1 Glucose (GLU)
- 1.2 Albumin (ALB)
- 1.3 Alkaline phosphatase (ALP)
- 1.4 Alanine aminotransferase (ALT)
- 1.5 Aspartate aminotransferase (AST)
- 1.6 Direct bilirubin (DBIL)
- 1.7 Total bilirubin (TBIL)
- 1.7 Blood Urea Nitrogen (BUN)
- 1.8 Cholesterol (CHOL)
- 1.9 Creatinine (CRE)
- 1.10 HDL-Cholesterol (HDL)
- 1.11 Lactate dehydrogenase (LDH)
- 1.12 LDL-Cholesterol (LDL)
- 1.13 Total Protein (TP)
- 1.14 Triglyceride (TG)
- 1.15 Urine analysis (UA)

2. Thyroid hormone

- 2.1 Thyroid-stimulating hormone (TSH)

3. Cancer markers

- 3.1 Carcinoembryonic antigen (CEA)

Inclusion criteria

1. Healthy group (n=12 cases), people are non-disease, whose results were in the reference range and had no injuries or blood loss before blood collection, aged 20 years and over.

2. Patient group (n=24 cases), people who had the disease included 8 patients with diabetes mellitus, 8 patients with hypercholesterolemia, and 8 patients with many chronic diseases (NCDs). (diabetes combined with hypercholesterolemia or high blood

pressure), without injuries or blood loss before the blood collection, aged 20 years and over.

Exclusion criteria

Pregnancy, anemia, cancer, hepatitis B and C infection, immunodeficiency (HIV), syphilis, and people who cannot collect enough blood volume.

Study 1: Comparison of the effects of the anti-coagulant-coated tube to the clinical test results.

Both formulas of Innomed blood collection tubes and control blood collection tubes (Z tube, Clot activator, Heparin, NaF and EDTA) were used to collect venous blood samples in 12 healthy volunteers and 24 patients with diabetes or NCD (n=36) to the biochemical analytes and CBC were analyzed by automatic analyzers as shown in (Figure 7-9). Each test were used triplicate measured and the result were analyzed by statistical significance of 0.05 and 0.017. The accept criteria include %Bias value < %Biasd value and %JHH and/or P-value > 0.05, 0.017

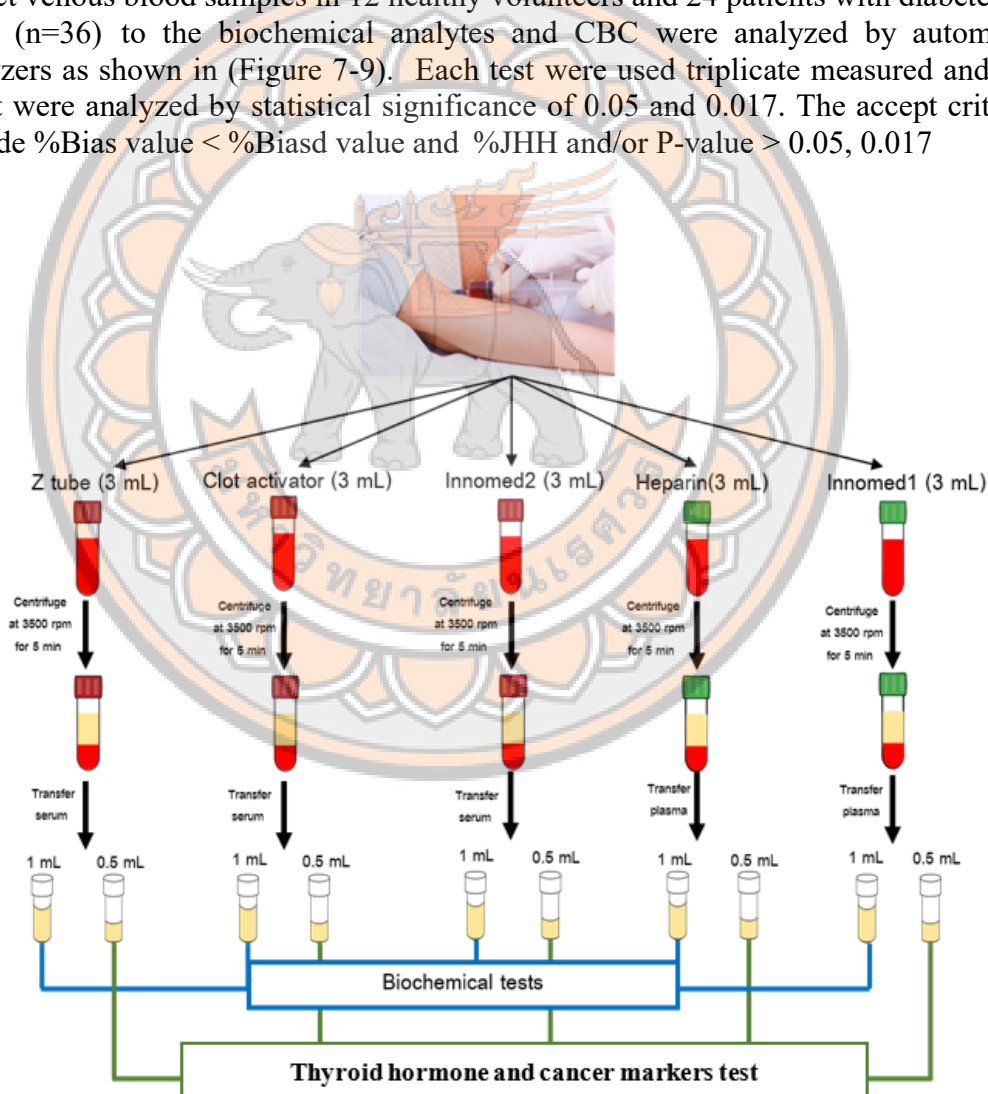


Figure 7 Schematic experimental study 1 for biochemical and thyroid hormone and cancer markers test setup

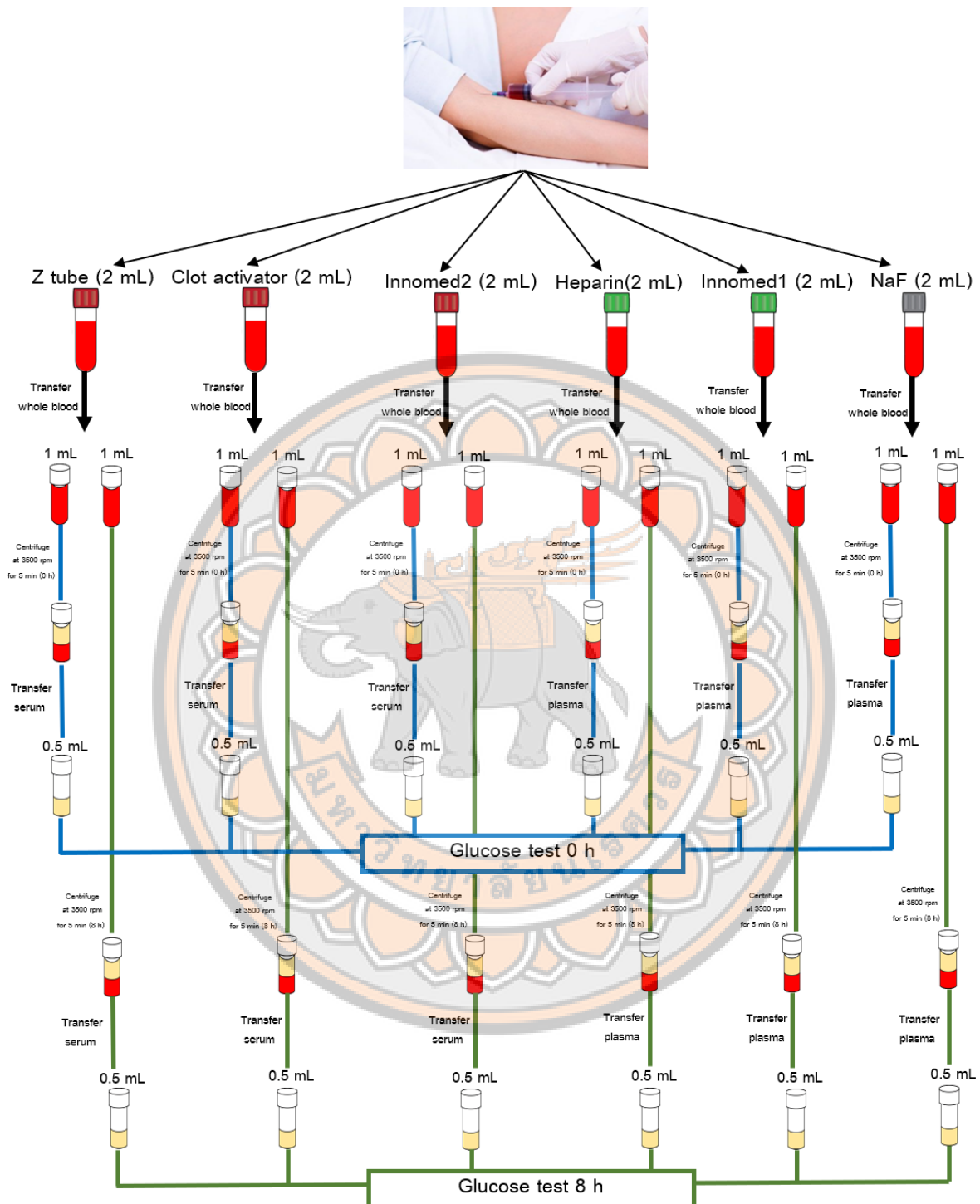


Figure 8 Schematic experimental study 1 for glucose tests setup

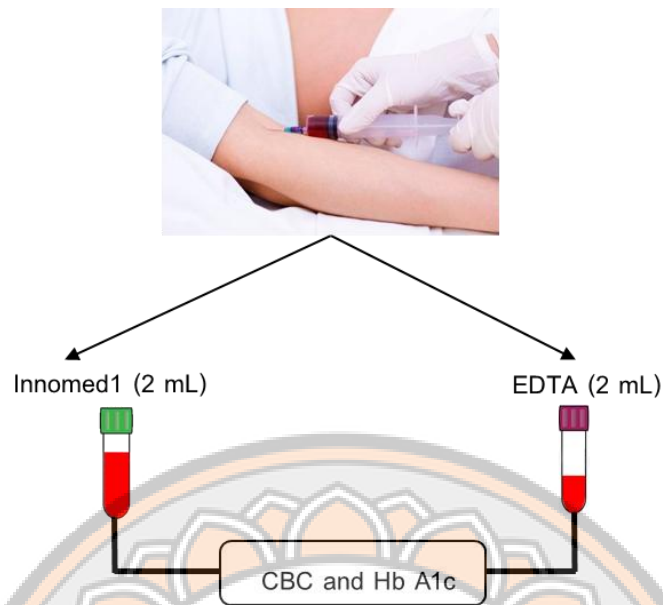


Figure 9 Schematic experimental study 1 for CBC and Hb A1c tests setup

Study 2: Determine the impact of the centrifugation time to biochemical measurement values.

The effect of centrifugation time is tested by measuring the biochemical test that represents the lysis of red blood cells. Innomed blood collection tubes and control blood collection tubes (Clot activator, and Heparin) were used to collect venous blood samples in 10 healthy people to measure the level of LDH (Figure 10-11). Each test were triplicate measured and the result were analyzed by statistically Mean, Median, IQR, %Bias < %Biasd value, and/or P-value > 0.05, 0.017 were evaluated.

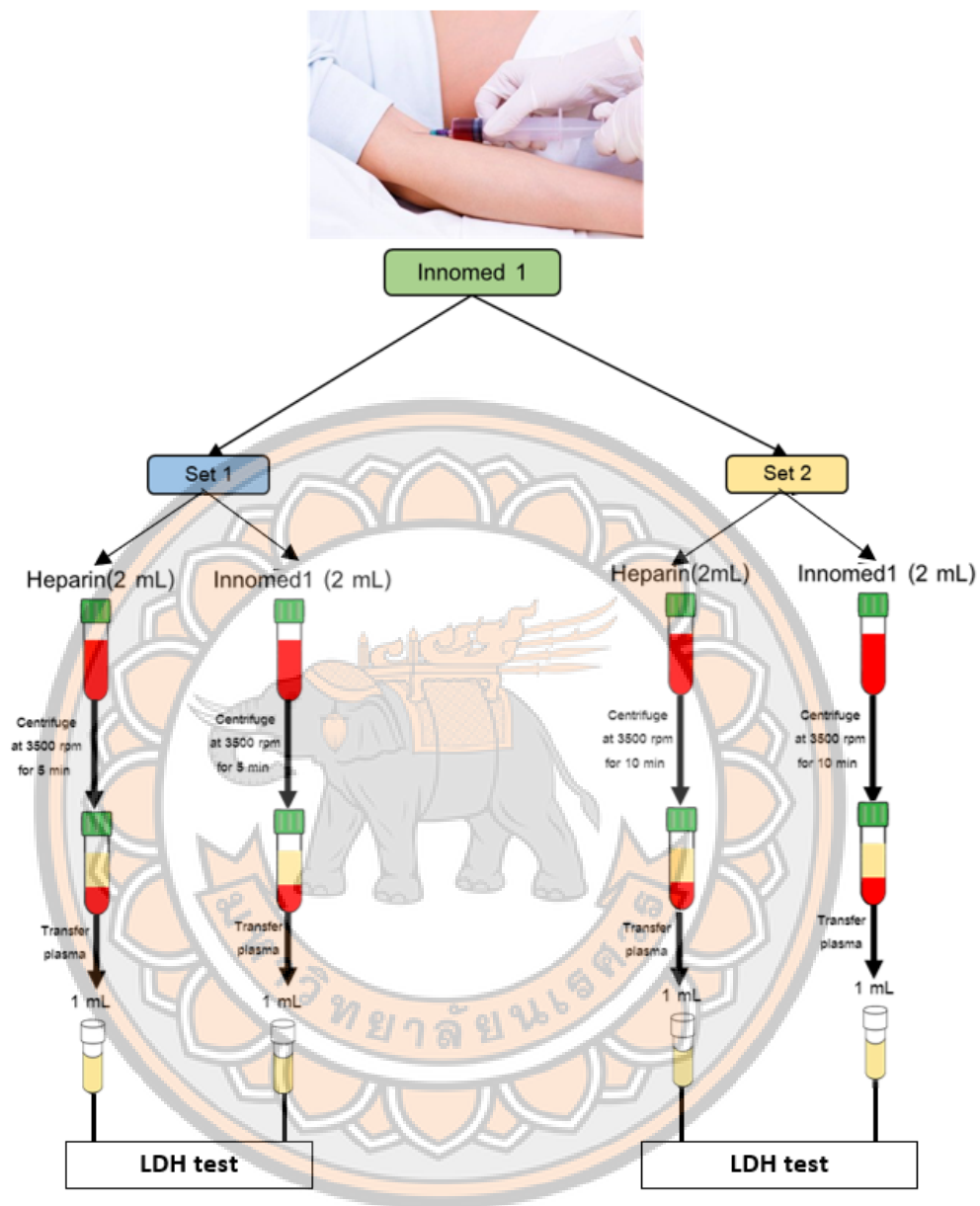


Figure 10 Schematic experimental study 2 for Innomed 1 (Formula 1) setup

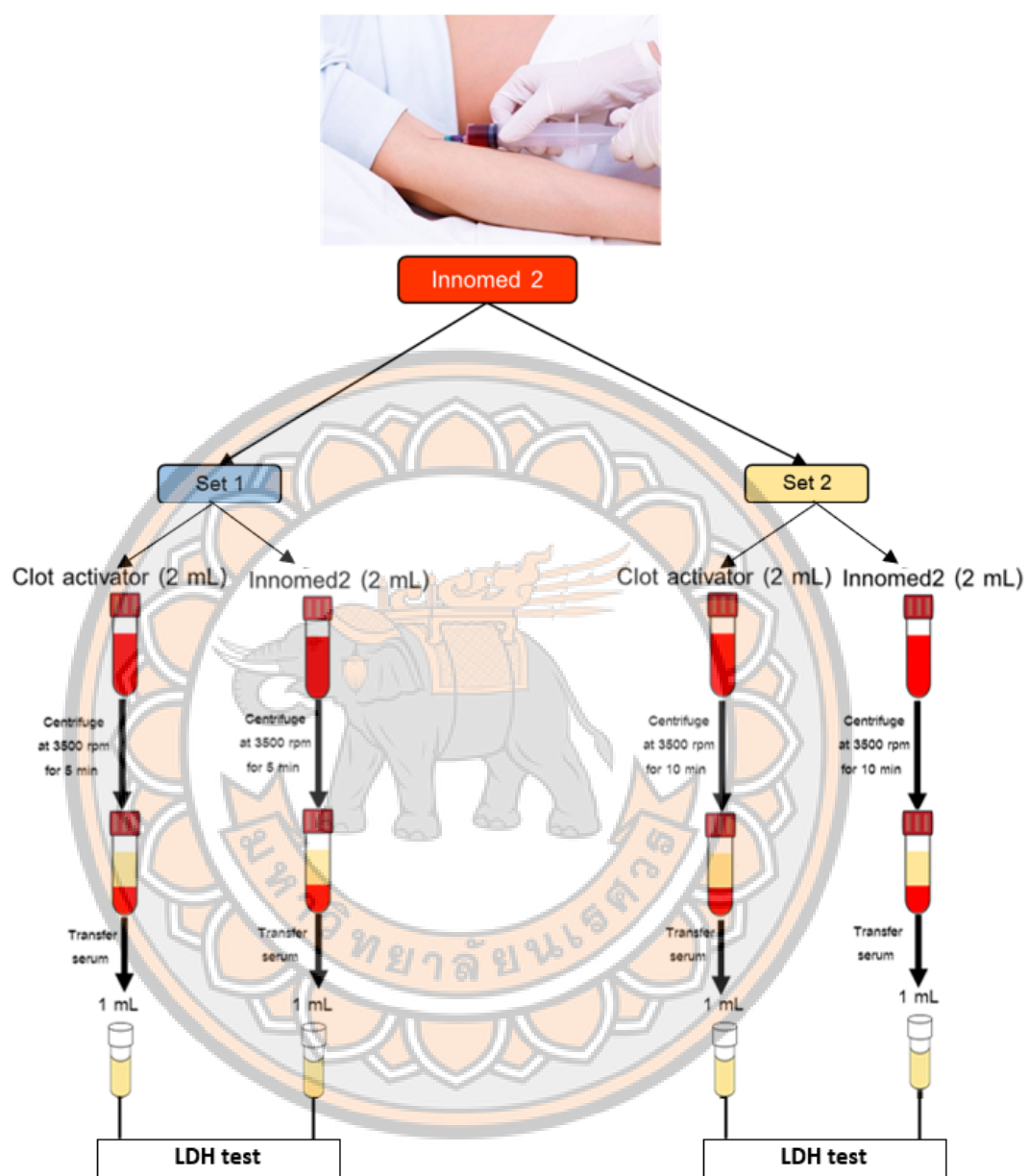


Figure 11 Schematic experimental study 2 for Innomed 2 (Formula 2) setup

Study 3: Determine the effects of blood collection techniques to biochemical analysis results.

The effect of vacuum and non-vacuum blood collection techniques is tested by measuring the biochemical test that represents the lysis of red blood cells. Both formulas of Innomed blood collection tubes and control blood collection tubes (Z tube, Clot activator and Heparin) used to collect venous blood samples in 10 healthy. The level of LDH were measured (Figure 12-13). Each test were triplicate measured, and the result were analyzed by statistically Mean, Median, IQR, %Bias < %Biasd value and/or P-value > 0.05, 0.017 were evaluated.

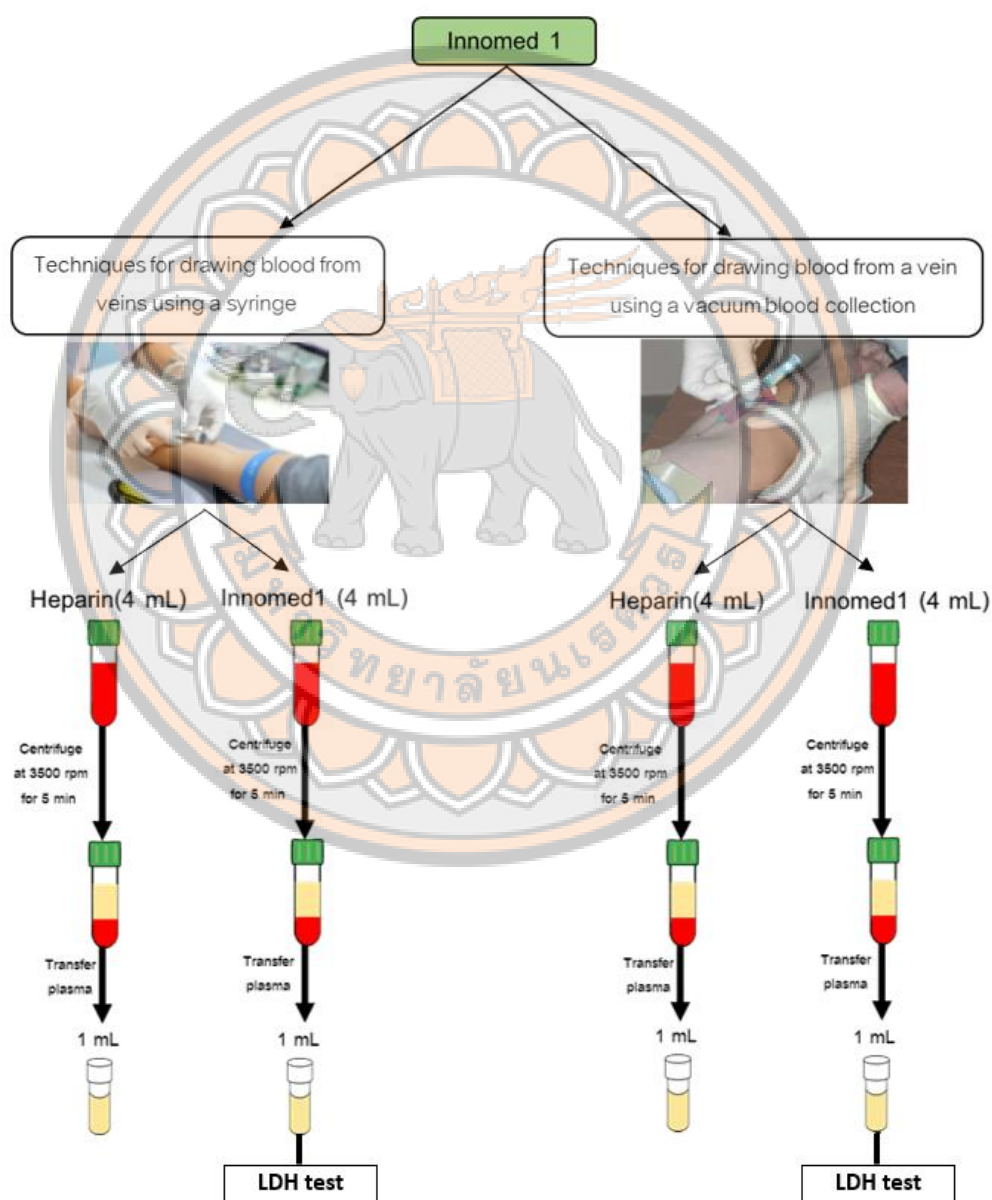


Figure 12 Schematic experimental study 3 for Innomed 1 (Formula 1) setup

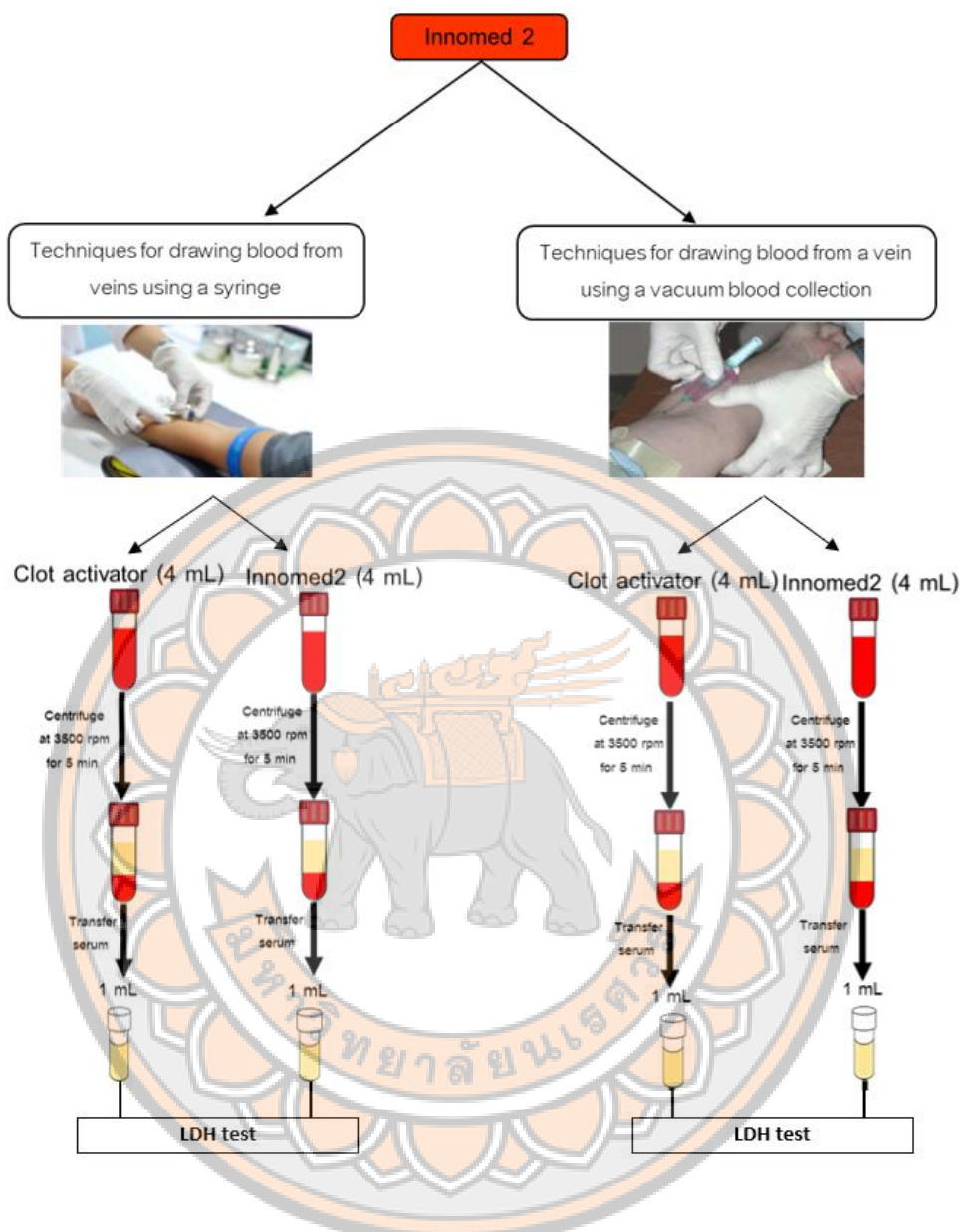


Figure 13 Schematic experimental study 3 for Innomed 2 (Formula 2) setup

Study 4: Determine the effects of storage time to RBC hemolysis.

The biological evaluation effects on individuals at different storage time is tested by measuring the biochemical test that represents the lysis of red blood cell. Both formulas of Innomed blood collection tubes and control blood collection tubes (Z tube, Clot activator, and Heparin) were used to collect venous blood samples in 10 healthy and stored at refrigerated temperatures for 0, and 24 hours. After storage times the level of LDH were measured by an automatic analyzer (Figure 14). Each test were triplicate measured, and the result were analyzed by statistically Mean, Median, IQR, %Bias < %Biasd value and/or P-value > 0.05, 0.017 were evaluated.

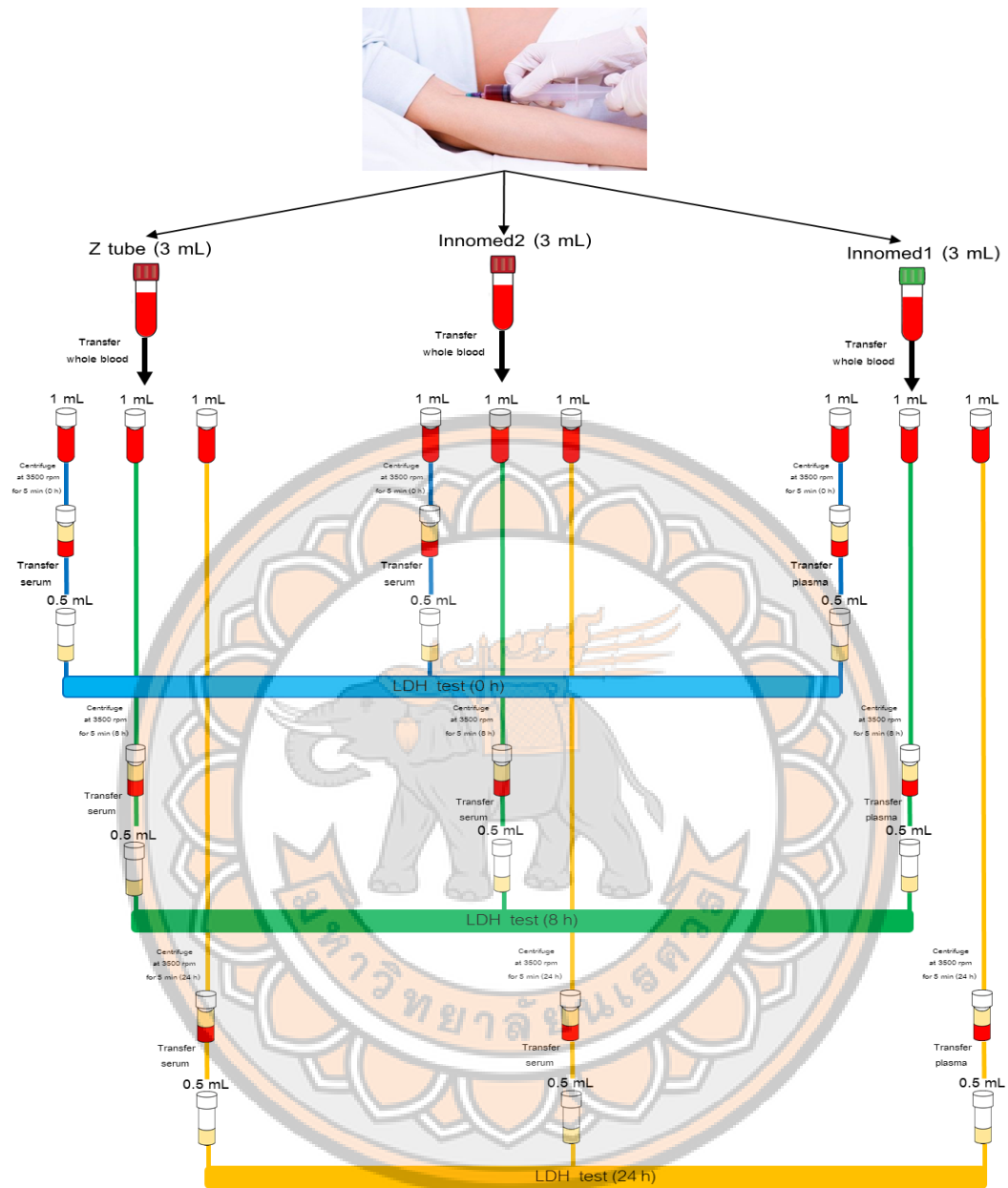


Figure 14 Schematic experimental study 4 setup

Study 5: Validation of the blood collection tubes by multicenter study

After the Innomed blood collection tube passes clinical evaluation, it were tested by 5 hospitals. Innomed blood collection tube were used and compared with a reference blood collection tube that is routinely used in the hospital laboratory (Figure 15). The biochemical or hematological test were requested as in Tables 2 and 3.

Inclusion Criteria for Participant Hospital

1. The hospital's laboratory must be certified by ISO 15189, the Medical Technological Council, the Ministry of Public Health, or the Royal College of Pathologists.
2. The laboratory has the results of external quality assurance (EQA) or proficiency testing (PT) in all test items used in the research project for at least the past 3 months.
3. The laboratory had %CV of participating tests that are calculated using internal quality control (IQC) data from the past two months were accepted by CLIA: 2019 (Clinical Laboratory Improvement Amendment) or other comparable criteria.

Exclusion Criteria for Hospital Participants

1. The hospital's laboratory has not been accredited.
2. The laboratory has external quality control (EQA) results, but the in-hospital quality control (IQA) results are not accepted by the specified criteria.

Table 2 Number of 5 hospitals and sample group selection in the Multi-center study

Hospitals	Sample		Parameter
	Healthy	Patient	
Hospital 1	10	10	• Biochemical • Thyroid function tests • Cancer markers tests
Hospital 2	10	10	
Hospital 3	10	10	
Hospital 4	10	10	
Hospital 5	10	10	
Total	100		

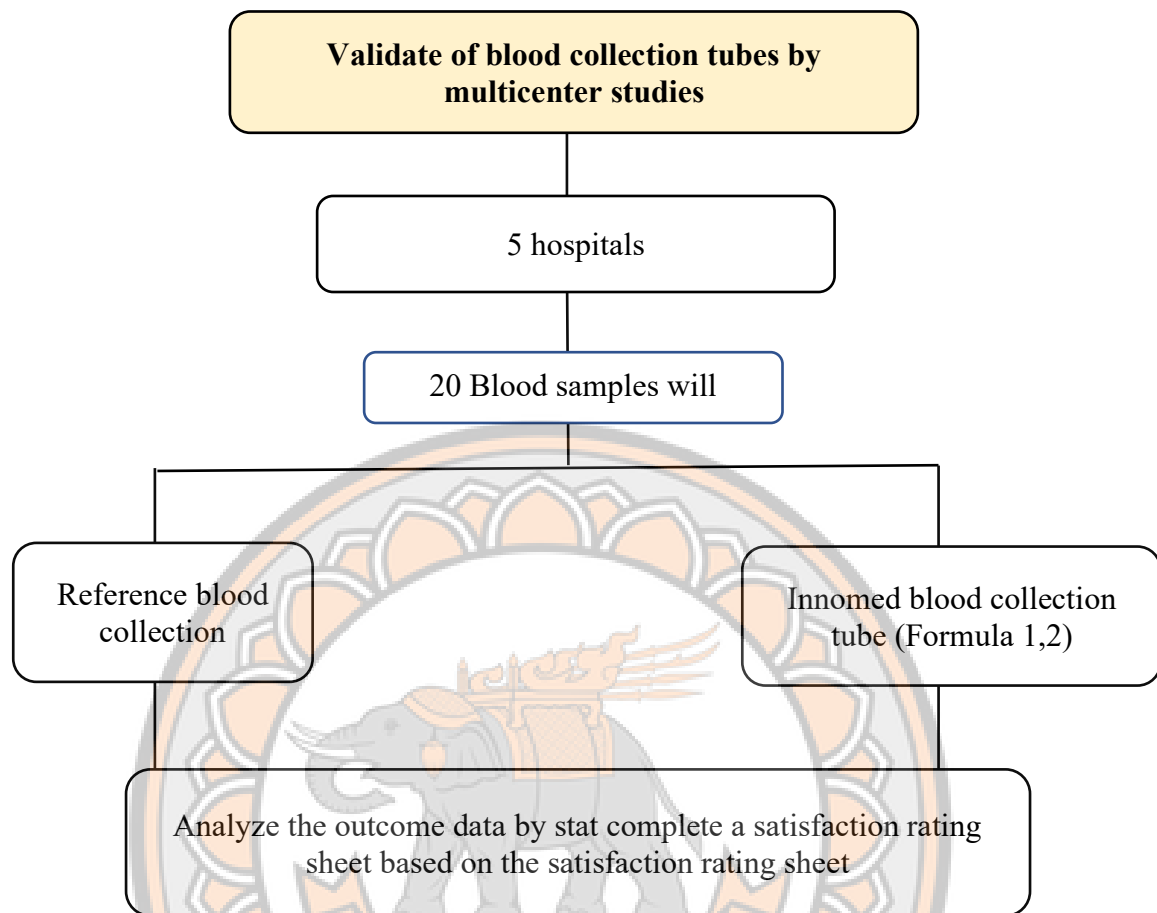


Figure 15 Validation of blood collection tubes by multicenter study

Research location, experiments, and data collection

Study 1-4: The research is conducted at the medical instrument research laboratory of Naresuan University.

Study 5: Testing is carried out at participating hospitals, a total of 5 hospitals, which include:

1. Maharaj Nakorn Chiang Mai Hospital
2. Buddhachinaraj Hospital
3. Sukhothai Hospital
4. Koh Samui Hospital
5. Police General Hospital

Table 3 Blood collection tubes used in this research

Test tubes		Reference tubes (Commercial tubes)				
						
Innomed Formula 1 (Lithium heparin and anti- glycolysis agents)	Innomed Formula 2 (Clot activator and anti- glycolysis agents)	Z-tubes	Heparin tube	Clot activator tube	NaF tube	K3/EDTA tube

Table 4 Automated analysis and participating hospitals

Hospital Name	Province	Automated Clinical Chemistry Analyzer		
		Model	Company	Country
Maharaj Nakorn Chiang Mai	Chiang Mai	Cobas 758	Roche	Switzerland
Buddhachinaraj	Phitsanulok	Beckman coulter AU5800	Beckman	USA
Sukhothai	Sukhothai	Mindray Model CL-6000i	Mindray	China
Koh Samui	Surat Thani	Beckman coulter AU 480	Beckman	USA
Police Genera	Bangkok	Abbott Accelerator a3600	Abbott	U.S.A.

Table 5 List of analyses and blood collection tubes tested at the participating hospitals in the multicenter study

Hospital	Innomed Tube	Parameter
Maharaj Nakorn Chiang Mai	Formula 1 (Heparin+Antiglycolysis)	Biochemical GLU, CHOL, TG, HDL, LDL, BUN, CRE, UA, AST, ALT, ALP, TBIL, DBIL, ALB, TP, LDH, Na ⁺ , K ⁺ , Cl ⁻ , HCO ₃
	Formula 2 (Clot activator+Antiglycolysis)	Biochemical GLU, CHOL, TG, HDL, LDL, BUN, CRE, UA, AST, ALT, ALP, TBIL, DBIL, ALB, TP, LDH, Na ⁺ , K ⁺ , Cl ⁻ , HCO ₃
Buddhachinaraj	Formula 1 (Heparin+Antiglycolysis)	Biochemical GLU, CHOL, TG, HDL, LDL, BUN, CRE, UA, AST, ALT, ALP, Ca, Mg, Phos Biochemical FT3, FT4, PSA Cancer markers tests CEA
	Formula 2 (Clot activator+Antiglycolysis)	Thyroid function tests TSH, FT3, FT4
Sukhothai	Formula 1 (Heparin+Antiglycolysis)	Biochemical GLU, CHOL, TG, HDL, LDL, BUN, CRE, UA, AST, ALT, ALP, TBIL, DBIL, Globulin, ALB, TP, LDH, Na ⁺ , K ⁺ , Cl ⁻ , HCO ₃
	Formula 2 (Clot activator+Antiglycolysis)	Thyroid function tests TSH, FT3, FT4
Koh Samui	Formula 1 (Heparin+Antiglycolysis)	Biochemical GLU, CHOL, TG, HDL, LDL, BUN, CRE, UA, AST, ALT, ALP, TBIL, DBIL, ALB, TP, LDH, Na ⁺ , K ⁺ , Cl ⁻ , HCO ₃ Thyroid function tests TSH, FT3, FT4, T3
	Formula 2 (Clot activator+Antiglycolysis)	Thyroid function tests TSH, FT3, FT4
Police Genera	Formula 1 (Heparin+Antiglycolysis)	Biochemical GLU, CHOL, TG, HDL, LDL, BUN, CRE, UA, AST, ALT, ALP, TBIL, DBIL, ALB, TP, LDH, Na ⁺ , K ⁺ , Cl ⁻ , HCO ₃
	Formula 2 (Clot activator+Antiglycolysis)	Biochemical GLU, CHOL, TG, HDL, LDL, BUN, CRE, UA, AST, ALT, ALP, TBIL, DBIL, ALB, TP, LDH, Na ⁺ , K ⁺ , Cl ⁻ , HCO ₃

CHAPTER IV

RESULTS AND DISCUSSION

Study 1: Comparison of the effects of the anti-coagulant-coated tube to the clinical test results.

Innomed Blood Collection Tube Formula 1

The clinical evaluation of Innomed Blood Collection Tube formula 1 (Heparin/antiglycolytic agent) was conducted following the CLSI GP34-A standard: "Validation and Verification of Tubes for Venous and Capillary Blood Specimen Collection." The tubes were used to collect blood from volunteer donors, and physical observations revealed no red blood cell lysis, fibrin formation, or clotting. Subsequently, blood specimens were analyzed for glucose levels, biochemical parameters, tumor markers, thyroid hormones, complete blood count (CBC), and hemoglobin A1c (HbA1c) as presented.

The evaluation showed that at the start of the 0-hour period (within 45 minutes after blood collection), up to 8 hours, the average glucose levels in Innomed Tubes formula 1 remained acceptable within at least 1 criterion compared to the reference tubes coated with sodium fluoride (NaF). Statistical analysis (p -value = 0.742) indicated no significant difference at a 95% confidence level. After 8 hours, the mean glucose value decreased by 7.62% from the initial time, well within the acceptable limit of a 10% reduction. Additionally, when considering the biological significance limit, the % Bias of the average glucose level at the start time was 1.03%, which was lower than the desirable % Bias_d value of 2.34%.

Comparing the HbA1c results with K3EDTA reference tubes, the evaluation met at least one criterion according to the accepted standard. The mean HbA1c values showed no significant difference ($p > 0.05$), and the % Bias was 0.00%, which was lower than the desirable % Bias_d value of 1.7%.

The CBC results using Innomed Tubes formula 1 met at least one criterion compared to K3EDTA reference tubes, following the accepted standard. The mean CBC values did not show a significant difference ($p > 0.05$) at the 95% confidence level, except for a statistically significant reduction in blood cell count.

Thyroid-Stimulating Hormone (TSH) results compared to lithium heparin reference tubes met at least one criterion based on the accepted standard. The mean TSH values showed no significant difference ($p > 0.05$), and the % Bias was 7.80%, which was lower than the desirable % Bias_d value.

The evaluation of tumor markers included Carcinoembryonic Antigen (CEA), which met at least one criterion compared to lithium heparin reference tubes. The mean CEA values showed no significant difference ($p > 0.05$), and the % Bias was 14.3% and 18.7%, both of which were lower than the desirable % Bias_d values.

The biochemical analysis included 15 parameters such as Cholesterol, Triglyceride, HDL, LDL, LDH, ALP, ALT, AST, ALB, TP, BIL-T, BIL-D, BUN, Creatinine, and Uric acid. The results for most of these parameters using the newly formulated coating were well within acceptable limits at a 95% confidence level, with p -values > 0.05 and/or % Bias values lower than the desirable % Bias_d and JHH values, as specified in the standard.

Table 6 Results of Clinical Evaluation of Innomed Tube 1 for Blood Glucose Levels at 0 and 8 Hours Compared to the Reference Tube in a Group of 24 Participants

Test	Sodium Fluoride (NaF/EDTA)				Innomed tube 1				Clinical Significance limits			Statistical Limit
	Range	Mean	SEM	% Decreased	Range	Mean	SEM	% Decreased	% Bias	% Bias _d	JHH	
Glucose (mg/dL) 0 Hr	69.4-141.7	87.0	2.56	0.00	75.0- 135.0	87.9	2.23	0.00	1.03	2.34	8	0.742
Glucose (mg/dL) 8 Hr	64.0-138.7	85.4	2.62	1.84	70.3- 124.0	81.2	1.97	7.62	4.92	2.34	8	0.190

Note: ($\pm$) SCL = (upper/lower) significant change limit, Bias_d= desirable quality specifications for bias, SEM = standard error of the mean, %Bias= difference between the compared tube results, Glu=Glucose, %Bias: Mean test- Mean target)/Mean target*100, %Bias_d: Bias desirable quality specifications for bias (<https://www.westgard.com/biodatabase1.htm>), %JHH: Percent changes in analyte (Johns Hopkins Hospital Laboratory Acceptability Thresholds) Acceptable criteria and significant limits of clinical limits and/or statistical limits ($P>0.05$) to 8 h <10%

Table 7 Results of Clinical Evaluation of Innomed Tube 1 for Complete Blood Count (CBC) and Hemoglobin A1c (HbA1c) Compared to Reference Tube and Control Tube in a Group of Healthy Volunteer Participants (n=12)

Analytes tested	Clinical significance limits				Reference			Test Tube		
	-SCL	+SCL	Biasd (%)	JHH (%)	Bias [†] (%)	EDTA [†]		Innomed Tube 1		Statistic al Limit
						Range	Mean (SEM)	Range	Mean (SEM)	
HbA _{1c} (%)	4.81	5.59	1.50	NA	0.00	4.97 - 5.40	5.20 (0.04)	4.90 - 5.40	5.20 (0.05)	0.820
RBC (106cells/uL)	3.26	5.94	1.70	NA	0.00	3.70 - 5.33	4.60 (0.15)	3.80 - 5.26	4.60 (0.15)	0.887
HGB (g/dL)	6.08	17.72	1.84	NA	1.68	7.10 - 14.80	11.90 (0.66)	7.27 - 14.63	12.10 (0.63)	0.911
HCT(%)	22.23	51.97	1.74	NA	0.27	25.33 - 45.10	37.10 (1.68)	25.47 - 43.97	37.20 (1.60)	0.950
MCV (fL)	51.66	109.74	1.26	NA	0.00	57.00 - 90.00	80.70 (3.28)	56.67 - 90.00	80.70 (3.32)	1.000
MCH (pg)	14.04	37.96	1.35	NA	0.38	15.83 - 29.73	26.00 (1.35)	16.20 - 29.77	26.10 (1.35)	0.955
MCHC (g/dL)	31.02	33.98	0.04	NA	0.31	31.77 - 33.30	32.50 (0.19)	31.83 - 33.40	32.60 (0.23)	0.794
RDW	8.30	19.50	1.70	NA	0.72	11.30 - 18.63	13.90	11.47 - 18.80	14.00	0.920

Analytes tested	Clinical significance limits				Reference		Test Tube		
	-SCL	+SCL	Biasd (%)	JHH (%)	Bias [†] (%)	EDTA [†]	Innomed Tube 1	Mean (SEM)	Statistic al Limit
						Range	Range	Mean (SEM)	p-value [†]
(%)								(0.63)	
PLT (103cells/uL)	48.20	479.80	5.90	NA	-41.33 [†]	184.33 - 383.67	41.33 - 332.67	264.00 (25.69)	154.90 (29.64)
WBT (103cells/uL)	-0.36	10.96	6.05	NA	-5.66	3.60 - 10.60	3.60 - 9.77	5.30 (0.64)	5.00 (0.57)
NEU (%)	15.70	52.50	9.25	NA	-4.40	23.77 - 40.73	23.13 - 43.13	34.10 (2.08)	32.60 (2.52)
LYM (%)	43.72	82.48	5.90	NA	-0.32	55.60 - 73.87	50.17 - 75.17	63.10 (2.19)	62.90 (2.75)
MON (%)	-0.53	3.73	13.20	NA	12.50	0.57 - 2.90	0.47 - 3.10	1.60 (0.24)	1.80 (0.24)
EOS (%)	-1.62	4.82	19.80	NA	12.50	-0.80 - 4.27	0.30 - 4.33	1.60 (0.41)	1.80 (0.45)
BAS (%)	-0.04	1.24	15.40	NA	0.00	0.33 - 1.07	0.37 - 0.83	0.60 (0.07)	0.60 (0.05)

Note: (±) SCL = (upper/lower) significant change limit, Bias_d = desirable quality specifications for bias, SEM = standard error of the mean, %Bias = difference between the compared tube results, HbA1c = Hemoglobin A1C, WBC = White Blood Cell, RBC = Red Blood Cell, HCT = Hematocrit, MCV = Mean Corpuscular Volume, MCH = Mean Corpuscular Width, PLT = Platelet, NEU = Neutrophil, LYM = Lymphocyte, MON = Monocyte, EOS = Eosinophil, BAS = Basophil, %Bias: Mean test- Mean target/Mean target*100, %Bias_d:

Bias desirable quality specifications for bias (<https://www.westgard.com/biodatabase1.htm>), Acceptable criteria and significant limits of clinical limits and/or statistical limits ($p>0.05$)

Table 8 Results of Clinical Evaluation of Innomed Tube 1 for Complete Blood Count (CBC) and Hemoglobin A1c (HbA1c) Compared to Reference Tube and Control Tube in a Group of Volunteer Patient Participants (n=24)

Analytes tested	Clinical significance limits				Reference		Test Tube		
	-SCL	+SCL	Biasd (%)	JHH (%)	Bias [†] (%)	EDTA [†]	Innomed Tube 1		Statistical Limit
							Range	Mean (SEM)	
HbA _{1c} (%)	4.16	7.25	1.50	NA	0.00	4.97 - 7.80	5.00 - 7.73	5.70 (0.11)	0.911
RBC (10 ⁶ cells/uL)	2.95	6.25	1.70	NA	0.00	3.70 - 6.20	3.77 - 5.73	4.60 (0.12)	0.224
HGB (g/dL)	9.62	16.78	1.84	NA	-1.52	10.53 - 15.20	10.57 - 15.17	13.20 (0.29)	0.123
HCT (%)	29.52	48.68	1.74	NA	-1.53	32.70 - 45.30	32.13 - 44.93	39.10 (0.76)	0.083
MCV (fL)	64.42	109.78	1.26	NA	-0.11	68.33 - 100.00	68.00 - 99.33	87.10 (1.69)	0.655
MCH (pg)	20.32	37.68	1.35	NA	0.34	21.53 - 34.30	21.47 - 34.20	29.00 (0.65)	0.361
MCHC (g/dL)	31.52	0.00	0.04	NA	0.00	31.50 - 34.20	30.93 - 34.57	33.40 (0.14)	0.948
RDW (%)	8.38	17.22	1.70	NA	0.00	10.20 - 17.83	10.07 - 17.47	12.80 (0.32)	0.958

Analytes tested	Clinical significance limits					Reference		Test Tube		
	-SCL	+SCL	Biasd (%)	JHH (%)	Bias [†] (%)	EDTA [†]		Innomed Tube 1		Statistical Limit
						Range		Range	Mean (SEM)	Mean (SEM)
PLT (103cells/uL)	98.46	339.14	5.90	NA	-12.34	152.33	- 304.00	106.00	- 287.67	191.80 (12.47)
WBT (103cells/uL)	2.20	9.60	6.05	NA	-5.08	3.67	- 8.40	3.93	- 8.10	5.60 (0.23)
NEU (%)	21.86	72.94	9.25	NA	-7.59	35.33	- 77.00	30.33	- 64.67	43.80 (1.72)
LYM (%)	24.62	63.38	5.90	NA	4.77	27.33	- 54.00	30.00	- 60.00	46.10 (1.60)
MON (%)	0.57	9.03	13.20	NA	-10.42	2.67	- 8.00	1.67	- 8.33	4.30 (0.31)
EOS (%)	-3.89	12.29	19.80	NA	4.76	1.00	- 11.33	1.00	- 11.67	4.40 (0.55)
BAS (%)	0.42	1.38	15.40	NA	11.11	0.33	- 1.00	0.67	- 1.33	1.00 (0.03)

Note: (±) SCL = (upper/lower) significant change limit, Bias_d = desirable quality specifications for bias, SEM = standard error of the mean, %Bias = difference between the compared tube results, HbA1c = Hemoglobin A1C, WBC = White Blood Cell, RBC = Red Blood Cell, HCT = Hematocrit, MCV = Mean Corpuscular Volume, MCH = Mean Corpuscular Width, PLT = Platelet, NEU = Neutrophil, LYM = Lymphocyte, MON = Monocyte, EOS = Eosinophil, BAS = Basophil, %Bias: Mean test- Mean target/Mean target*100, %Bias_d: Bias desirable quality specifications for bias (<https://www.westgard.com/biodatabase1.htm>), Acceptable criteria and significant limits of clinical limits and/or statistical limits ($p > 0.05$)

Innomed Blood Collection Tube Formula 2

The clinical evaluation of Innomed blood collection tube formula 2 (Clot activator/antiglycolytic agent) was conducted following the CLSI GP34-A standard: "Validation and Verification of Tubes for Venous and Capillary Blood Specimen Collection." The tubes were used to collect blood from volunteer donors, and physical observations revealed no red blood cell lysis, fibrin formation, or clotting within the specified time. Subsequently, blood specimens were analyzed for glucose levels, biochemical parameters, tumor markers, thyroid hormones,

The evaluation showed that at the start of the 0-hour period (within 45 minutes after blood collection), up to 8 hours, the average glucose levels in Innomed tubes formula 2 remained acceptable within at least 1 criterion compared to the reference tubes coated with sodium fluoride (NaF). Statistical analysis (p -value = 0.833) indicated no significant difference at a 95% confidence level. After 8 hours, the mean glucose value decreased by 5.9% from the initial time, well within the acceptable limit of a 10% reduction. Additionally, when considering the biological significance limit, the % Bias of the average glucose level at the start time decreased by -1.09%, which was lower than the desirable % Bias_d value of 2.34%.

Thyroid-Stimulating Hormone (TSH) results compared to reference and control tubes met at least one criterion based on the accepted standard. The mean TSH values showed no significant difference ($p > 0.05$), and the % Bias was 7.80%, which was lower than the desirable % Bias_d value.

The evaluation of tumor markers included Carcinoembryonic Antigen (CEA), which met at least one criterion compared to reference and control tubes. The mean CEA values showed no significant difference ($p > 0.05$), and the % Bias was 14.3%, which was lower than the desirable % Bias_d value.

The biochemical analysis included 15 parameters such as Cholesterol, Triglyceride, HDL, LDL, LDH, ALP, ALT, AST, ALB, TP, BIL-T, BIL-D, BUN, Creatinine, and Uric acid. The results for most of these parameters using the newly formulated coating were well within acceptable limits at a 95% confidence level, with p -values > 0.05 and/or % Bias values lower than the desirable % Bias_d and JHH values, as specified in the standard.

Table 9 Results of Clinical Evaluation of Innomed Tube 2 (Clot activator/antiglycolytic) for Blood Glucose Level Maintenance at 0 and 8 Hours Compared to Reference Tube (n=24)

Test	Sodium Fluoride (NaF/EDTA)					Innomed tube 2					Clinical Significance limits			Statistical Limit
	Range	Mean	SEM	% Decreased	Range	Mean	SEM	% Decreased	% Bias	% Bias _d	JH	H	P-value	
Glucose (mg/dL) 0 Hr	69-246	119	14.13	0.0	70-232	118	13.64	0.0	-1.09	2.34	8	8	0.947	
Glucose (mg/dL) 8 Hr	64-239	115	14.32	3.36	62-229	111	13.89	5.9	-3.74	2.34	8	8	0.833	

Note: ($\pm$) SCL = (upper/lower) significant change limit, Bias_d = desirable quality specifications for bias, SEM = standard error of the mean, %Bias = difference between the compared tube results Glu = Glucose %Bias: Mean test - Mean target / Mean target * 100, %Bias_d: Bias desirable quality specifications for bias (<https://www.westgard.com/biobase1.htm>), %JHH: Percent changes in analyte (Johns Hopkins Hospital Laboratory Acceptability Thresholds), Acceptable criteria and significant limits of clinical limits and/or statistical limits (P>0.05) to 8 h <10%

Table 10 Results of Clinical Evaluation of Innomed Tube 2 for Biochemical Analysis Compared to the Reference Tube and Control Tube in a Group of 12 Healthy Volunteer Participants

Analytes tested	Clinical significance limits					Reference			Control Tube			Test Tube		
	-SCL	+SCL	Bias d (%)	JH H (%)	Bias [†] (%)	Bias* (%)	Z tube [†] Range	Mean (SEM)	Clot activator tube* Range	Mean (SEM)	Innomed Tube 2 Range	Mean (SEM)	P-value [†]	Statistical Limit P-value*
ALB (g/dL)	3.48	6.12	1.43	7	0.00	0.00	4.00 - 5.43	4.80 (0.14)	4.10 - 5.50	4.80 (0.13)	4.10 - 5.37	4.80 (0.12)	0.939	0.706
ALP (U/L)	8.92	142.88	6.72	10	-0.13	-0.92	40.67 - 106.00	75.90 (6.91)	41.00 - 105.00	76.50 (6.73)	40.33 - 104.00	75.80 (6.59)	0.989	0.942
ALT (U/L)	5.49	20.11	11.48	15	0.00	1.59	9.33 - 16.33	12.80 (0.79)	9.67 - 16.00	12.60 (0.73)	9.67 - 17.00	12.80 (0.84)	0.979	0.851
AST (U/L)	8.59	32.61	6.54	10	-5.83	6.01	14.67 - 30.00	20.60 (1.24)	11.00 - 27.67	18.30 (1.27)	13.00 - 29.00	19.40 (1.20)	0.516	0.511
BIL-D (mg/dL)	0.06	0.34	14.20	NA	0.00	0.00	0.11 - 0.27	0.20 (0.01)	0.10 - 0.31	0.20 (0.02)	0.10 - 0.31	0.20 (0.02)	0.760	0.953
BIL-T (mg/dL)	-0.05	0.85	8.95	10	0.00	0.00	0.21 - 0.68	0.40 (0.05)	0.23 - 0.76	0.40 (0.05)	0.24 - 0.76	0.40 (0.05)	0.788	0.814
BUN (mg/dL)	3.36	20.84	5.57	10	-0.83	-0.83	8.00 - 18.00	12.10 (0.90)	8.00 - 18.00	12.10 (0.90)	7.67 - 18.00	12.00 (0.91)	0.93	0.920
CHOL (mg/dL)	90.14	270.46	4.10	5	0.00	-0.44	144.33 - 243.33	180.30 (9.30)	145.00 - 244.00	181.10 (9.53)	143.33 - 242.33	180.30 (9.51)	0.998	0.953
CRE	0.32	1.28	3.96	7	0.00	0.00	0.58 - 1.11	0.80	0.60 - 1.15	0.80	0.60 - 1.13	0.80	0.984	0.868

Analytes tested	Clinical significance limits				Reference		Control Tube		Test Tube					
	-SCL	+SCL	Bias d (%)	JH H (%)	Bias [†] (%)	Bias * (%)	Z tube [†] Range	Mean (SEM)	Clot activator tube* Range	Mean (SEM)	Innomed Tube 2 Range	Mean (SEM)	Statistical Limit P- value [†]	P- value*
(mg/dL)								(0.05)		(0.05)		(0.05)		
HDL	9.39	94.01	5.61	10	-0.19	-0.77	30.00 - 77.00	51.70	30.00 - 77.00	52.00	30.00 - 75.00	51.60	0.935	0.890
(mg/dL)								(4.36)		(4.35)		(4.15)		
LDH	85.71	360.89	4.30	10	-18.58	10.79	138.47 - 317.77	223.30	127.33- 212.83	164.10	160.20 - 233.77	164.10	0.017	0.073
(U/L)								(14.19)		(6.75)		(6.75)		
LDL	22.24	185.76	5.46	10	1.63	0.09	62.33 - 146.33	104.00	62.67 - 148.33	105.60	61.33 - 148.33	105.70	0.891	0.998
(mg/dL)								(8.43)		(8.35)		(8.32)		
TP	5.37	9.23	1.36	5	1.37	0.00	6.00 - 8.03	7.30	6.53 - 8.10	7.40	6.60 - 8.10	7.40	0.564	0.980
(g/dL)								(0.20)		(0.16)		(0.15)		
TRIG	7.70	198.50	9.57	5	1.65	-0.29	33.00 - 164.00	103.10	42.67 - 167.67	105.10	42.00 - 164.67	104.80	0.903	0.929
(mg/dL)								(9.84)		(9.61)		(9.35)		
UA	1.08	10.72	4.87	10	-3.39	0.00	3.53 - 9.10	5.90	3.30 - 8.80	5.70	3.33 - 8.73	5.70	0.835	0.942
(mg/dL)								(0.50)		(0.50)		(0.50)		

Note: (±) SCL = (upper/lower) significant change limit, Bias = desirable quality specifications for bias, SEM = standard error of the mean, %Bias = difference between the compared tube results, Glu = Glucose, BUN = Blood urea nitrogen, CER = Creatinine, CHOL = Total cholesterol, TRIG = Triglyceride, HDL = High-density lipoprotein, LDL = Low-density lipoprotein, UA = Uric acid, AST = Aspartate aminotransferase, ALT = Alanine aminotransferase, ALP = Alkaline phosphatase, BIL-D = Direct bilirubin, BIL-T = Total bilirubin, ALB = Albumin, LDH = lactate dehydrogenase, TSH = Thyroid stimulating hormone, CEA = Carcinoembryonic antigen, %Bias: Mean test- Mean target / Mean target * 100, %Bias: Bias desirable quality specifications for bias (https://www.westgard.com/biodatabase1.htm), %JHH: Percent changes in analyte (Johns Hopkins Hospital Laboratory Acceptability Thresholds), Acceptable criteria and significant limits of clinical limits and/or statistical limits (p > 0.05)

Table 11 Results of Clinical Evaluation of Innomed Tube Model B for Biochemical Analysis Compared to the Reference Tube and Control Tube in a Group of 24 Volunteer Patient Participants

HDL	7.42	85.38	5.61	10.00	1.72	1.51	30.00 -	77.33	46.40	30.00 - 82.00	46.50	30.00 - 82.00	47.20	0.86	0.878
(mg/dL)									(3.11)		(3.35)		(3.34)		
LDH	79.52	333.88	4.30	10.00	- 8.71	8.26	115.50 -	299.07	206.70	137.03-254.97	174.30	147.93 - 292.17	188.70	0.22	0.242
(U/L)									(11.02)		(7.91)		(9.18)		
LDL	-22.53	314.93	5.46	10.00	- 0.96	-0.07	63.67 -	350.00	146.20	67.00 - 355.00	144.90	64.67 - 356.00	144.80	0.94	0.993
(mg/dL)									(13.47)		(13.7) 2		(13.69)		
TP	5.70	8.50	1.36	5.00	1.41	0.00	6.00 -	8.30	7.10	6.53 -	7.70	6.60	7.70	7.20	0.928
(g/dL)									(0.11)		(0.08)		(0.07)		
TRIG	- 134.37	597.77	9.57	5.00	- 0.39	0.74	112.67 -	624.33	231.70	118.33-621.33	229.10	117.67 - 616.67	230.80	0.98	0.967
(mg/dL)									(29.23)		(27.97)		(27.98)		
UA	1.02	12.78	4.87	10.00	- 2.90	0.00	3.53 -	11.20	6.90	3.30 -	10.77	6.70	3.33	11.10	0.944
(mg/dL)									(0.48)		(0.48)		(0.49)		
TSH	-0.70	4.50	14.14	NA	- 5.26	0.00	0.35 -	3.30	1.90	0.35 -	3.31	1.80	0.35	3.28	0.987
(mIU/MI)									(0.29)		(0.30)		(0.29)		
CEA	0.34	6.66	14.30	NA	- 2.86	0.00	1.60 -	0.00	3.50	1.67 -	4.85	3.40	1.67	4.80	0.959
ng/dL									(0.36)		(0.32)		(0.32)		

Note: (±) SCL = (upper/lower) significant change limit, Biasd= desirable quality specifications for bias, SEM = standard error of the mean, %Bias= difference between the compared tube results, Glu=Glucose, BUN = Blood urea nitrogen, CER = Creatinine, CHOL= Total cholesterol, TRIG = Triglyceride, HDL = High-density lipoprotein, LDL = Low-density lipoprotein, UA = Uric acid, AST = Aspartate aminotransferase, ALT = Alanine aminotransferase, ALP = Alkaline phosphatase, BIL-D= Direct bilirubin, BIL-T= Total bilirubin, ALB= Albumin, LDH=lactate dehydrogenase, TSH= Thyroid stimulating hormone, CEA = Carcinoembryonic antigen , %Bias: Mean test- Mean target)/Mean target* 100, %Biasd: Bias desirable quality specifications for bias (<https://www.westgard.com/biobase1.htm>), %JHH: Percent changes in analyte (Johns Hopkins Hospital Laboratory Acceptability Thresholds), Acceptable criteria and significant limits of clinical limits and/or statistical limits (p>0.05)

Study 2: Determine the impact of the centrifugation time to biochemical measurement values.

The study found that centrifugation times of 5 minutes and 10 minutes for Innomed blood collection tubes, formulas 1 and 2, did not have statistically significant effects on lactate dehydrogenase (LDH) levels. Both formulas exhibited no significant statistical differences in LDH levels when comparing the two different centrifugation times, 5 minutes and 10 minutes, used in this study. This suggests that the choice between a 5-minute and 10-minute centrifugation time may not impact LDH level measurements in Innomed blood collection tubes, formulas 1 and 2, in a statistically significant.

Table 12 The effects of two different centrifugation times on LDH in Innomed blood collection tube formula 1

Innomed blood collection tube formula 1 N=10	5 minute centrifugation*				10 minute centrifugation*				P- value
	Median		IQR		Median		IQR		
LDH (U/L)	174	131	-	229	174	129	-	228	0.859

Note: Innomed blood collection tube formula 1 - Heparin+Antiglycolysis. IQR - interquartile range, lactate dehydrogenase. $P < 0.05$ was considered statistically significant. *Centrifuged at 3500 rpm.

Table 13 The effects of two different centrifugation times on LDH in Innomed blood collection tube formula 2

Innomed blood collection tube formula 2 N=10	5 minute centrifugation				10 minute centrifugation				P-value
	Median	IQR			Median	IQR			
LDH (U/L)	169	128	-	217	169	130	-	216	0.915

Note: Innomed blood collection tube formula 2 – Clot activator +Antiglycolysis. IQR - interquartile range, lactate dehydrogenase. $P < 0.05$ was considered statistically significant. *Centrifuged at 3500 rpm.

Study 3: Determine the effects of blood collection techniques to biochemical analysis results.

Innomed blood collection tube formula 1

For blood samples collected using the needle-syringe system, the mean lactate dehydrogenase (LDH) level was 175 U/L. The median LDH level was 174 U/L with an Interquartile Range (IQR) of 131-223. The % Bias was calculated at 3.0%. The P-value when compared with the Heparin tube results was 0.654.

For blood samples collected using the vacuum extraction system, the mean LDH level was 179 U/L. The median LDH level was 174 U/L with an IQR of 131-229. The % Bias was calculated at 1.0%. The P-value when compared with the Heparin tube results was 0.879.

When comparing the two blood collection methods, the % Bias between the results from Innomed tube formula 1 and Heparin tube was 4.3%. The P-value for comparing this bias was 0.754.

Innomed blood collection tube formula 2

For samples collected through the needle-syringe system. The mean lactate dehydrogenase (LDH) level was recorded at 174 U/L. The median LDH level amounted to 168 U/L, with an Interquartile Range (IQR) spanning 127-233. The % Bias was computed as 4.25%. The P-value when juxtaposed against results from the Clot activator tube was determined to be 0.550.

For samples collected through the vacuum extraction system. The mean LDH level registered a value of 171 U/L. The median LDH level was 163 U/L, characterized by an IQR ranging from 128 to 237. The % Bias was established at 1.12%. The P-value, in comparison with results from the Clot activator tube, was identified as 0.888.

Comparative analysis of the blood collection methods revealed. % Bias of 0.831% between results originating from Innomed tube formula 2 and the Clot activator tube. P-value of 0.835 is associated with the comparison of this bias.

The study revealed that the choice of blood collection technique did not result in statistically significant differences in LDH levels within the Innomed blood collection tubes. The % Bias values for both comparisons were relatively low, and the associated P-values indicated no significant statistical differences. The findings suggest that the selection of blood collection technique might not have a significant impact on LDH measurements in the Innomed blood collection tubes, for both formula 1 and formula 2.

Table 14 The effects of two different blood collection techniques on LDH results in Innomed blood collection tube formula 1

Test	Blood collection tube (N=10)	Blood collected by needle-syringe system				Blood collected by vacuum extraction system				Comparison of blood collection methods (P)
		Mean	Median (IQR)	% Bias	P value	Mean	Median (IQR)	% Bias	P value	
LDH (U/L)	Innomed tube formula 1	175	174 (131-223)			179	174 (131-229)			0.754
	Heparin tube	170	172 (128-195)	3.0	0.654	177	172 (117-172)	1.0	0.879	

Note: IQR - interquartile range. %Bias - difference between Innomed tube formula 1 results and Heparin tube results. Biasd - desirable quality specifications for bias. LDH, lactate dehydrogenase; $P < 0.05$ was considered statistically significant.

Table 15 The effects of two different blood collection techniques on LDH results in Innomed blood collection tube formula 2

Test	Blood collection tube (N=10)	Blood collected by needle-syringe system				Blood collected by vacuum extraction system				Comparison of blood collection methods (P)
		Mean	Median (IQR)	% Bias	P value	Mean	Median (IQR)	% Bias	P value	
LDH (U/L)	Innomed tube formula 2	174	168 (127-233)	4.25	0.550	171	163 (128-237)	1.12	0.888	0.831
	Clot activator tube	167	161 (127-220)			169	165 (130-230)			

Note: IQR - interquartile range. %Bias - difference between Innomed tube formula 2 results and Clot activator tube results. Biasd - desirable quality specifications for bias. LDH, lactate dehydrogenase; $P < 0.05$ was considered statistically significant.

Study 4: Determine the effects of storage time to RBC hemolysis.

Innomed tube formula 1

At the 0 hours storage time point The mean lactate dehydrogenase (LDH) level was recorded as 177 U/L. The median LDH level was measured at 174 U/L, accompanied by an Interquartile Range (IQR) spanning from 142 to 318. The % Bias was calculated at 21.57%. The P-value, when compared to the Z tube, was determined to be 0.023.

At the 24 hours storage time point. The mean LDH level increased to 196 U/L. The median LDH level also rose to 191 U/L, with an IQR ranging from 159 to 278. The % Bias decreased to 15.62%. The P-value in comparison with the Z tube was found to be 0.070.

An analysis of the two storage timeframes revealed % Bias of 4.3% between the LDH results at 0 hours and 24 hours for Innomed tube formula 1. The associated P-value for this bias comparison was recorded as 0.780.

Innomed tube formula 2

At the 0 hours storage time point. The mean LDH level was determined as 174 U/L. The median LDH level was 168 U/L, accompanied by an IQR ranging from 127 to 233. The % Bias was computed as 22.9%. The P-value, when compared to the Z tube, was found to be 0.018.

At the 24 hours storage time point. The mean LDH level further increased to 188 U/L. The median LDH level reached 183 U/L, characterized by an IQR spanning from 141 to 263. The % Bias decreased to 18.76%. The P-value in comparison with the Z tube was identified as 0.033.

Upon analyzing the storage timeframes % Bias of 4.3% was observed between LDH results at 0 hours and 24 hours for Innomed tube formula 2. The P-value linked to this bias comparison was recorded as 0.018.

The storage time significantly affected LDH results in both formula 1 and formula 2 cases. The % Bias values for the comparison of storage times were relatively low, and the associated P-values indicated statistically significant differences. The study demonstrated that longer storage times led to changes in LDH levels within Innomed blood collection tubes for both formula 1 and formula 2.

Table 16 Results of Biochemical Analysis of Plasma Stored in Lithium Heparin Control Tubes and Innomed Tube 1 (Heparin+Antiglycolysis) Using Cobas 758 Automated Analyzer at Maharaj Chiang Mai Hospital, Healthy Volunteer Group (n=10)

Test	Control Tube		Test Tube		Acceptable Criteria & Significance			
	Heparin Tube		Innomed Tube 1		(Heparin/antiglycolytic agent)			
	Range	Mean (SEM)	Range	Mean (SEM)	Bias	Bias ^d	JHH*	P-value
GLU (mg/dL)	81.8 -104.8	90.5 (2.27)	87.7-107.5	94.3 (1.94)	4.20 ⁺	2.34	8	0.293
ALB (g/dL)	4.0-4.7	4.4 (0.06)	3.96-4.56	4.37 (0.05)	0.68	1.43	7	0.791
ALP (U/L)	56.0-101.0	73.3 (4.53)	56.0-101.0	72.3 (4.53)	1.36	6.72	10	0.902
ALT (U/L)	9.6-49.5	22.8 (4.49)	10.4-49.7	22.5 (4.48)	1.32	11.48	15	0.967
AST (U/L)	7.9-32.5	15.0 (2.21)	6.0-31.5	14.8 (2.33)	1.33	6.54	10	0.932
BIL-D (mg/dL)	0.09-0.36	0.20 (0.03)	0.10-0.39	0.21 (0.03)	5.00	14.20	NA	0.891
BIL-T (mg/dL)	0.18-0.84	0.50 (0.07)	0.21-0.81	0.50 (0.07)	0.00	8.95	10	0.967
BUN (mg/dL)	6.4-18.9	13.0 (1.34)	6.4-18.8	12.9 (1.29)	0.77	5.57	10	0.940

Test	Control Tube		Test Tube		Acceptable Criteria & Significance			
	Heparin Tube (Commercial Tube)		Innomed Tube 1 (Heparin/antiglycolytic agent)					
	Range	Mean (SEM)	Range	Mean (SEM)	Bias	Bias ^d [†]	JHH*	P-value
CHOL (mg/dL)	167.7-253.1	196.1 (10.10)	166.3-249.8	193.5 (9.83)	1.33	4.10	5	0.868
CRE (mg/dL)	0.59-0.98	0.72 (0.04)	0.59-0.96	0.73 (0.4)	1.39	3.96	7	0.934
HDL (mg/dL)	42.3-71.8	53.7 (2.98)	42.0-71.3	53.2 (2.97)	0.93	5.61	10	0.917
LDH (U/L)	111-187	157 (7.67)	108-178	142 (6.12)	-9.25 [†]	4.30	10	0.158
LDL (mg/dL)	94.2-174.7	123.8 (8.67)	94.8-173.1	122.3 (8.49)	-1.21	5.46	10	0.901
TP (g/dL)	7.30-8.14	7.78 (0.08)	7.19-8.03	7.70 (0.08)	-1.03	1.36	5	0.479
TRIG (mg/dL)	55.7-204.1	121.9 (14.59)	54.2-206.5	121.2 (14.70)	-0.57	9.57	5	0.968
UA (mg/dL)	4.9-8.9	6.10 (0.37)	4.9-8.8	6.06 (0.36)	-0.66	4.87	10	0.970
Na ⁺ (mmol/L)	136.3-142.1	139.3 (0.63)	139.2-144.4	141.90 (0.52)	1.87 [†]	0.23	3	0.004
K ⁺ (mmol/L)	3.3-4.2	3.84 (0.07)	3.4-4.2	3.85 (0.07)	0.26	1.81	8	0.968
Cl ⁻ (mmol/L)	100.6-104.3	102.9	102.9-107.8	105.4	2.43 [†]	0.50	5	<0.005

Test	Control Tube		Test Tube		Acceptable Criteria & Significance		
	Heparin Tube (Commercial Tube)		Innomed Tube 1 (Heparin/antiglycolytic agent)				
	Range	Mean (SEM)	Range	Mean (SEM)	Bias	Bias ^d	Statistical Limit
HCO ₃ ⁻ (mmol/L)	20.9-27.4	24.70 (0.70)	20.8-27.7	24.8 (0.67)	0.40	1.70	0.894

Note: SEM = standard error of the mean, %Bias= difference between the compared tube results, Glu =Glucose, BUN = Blood urea nitrogen,CER = Creatinine, CHOL= Total cholesterol, TRIG = Triglyceride, HDL = High-density lipoprotein, LDL = Low-density lipoprotein, UA = Uric acid, AST = Aspartate aminotransferase, ALT = Alanine aminotransferase, ALP = Alkaline phosphatase, BIL-D= Direct bilirubin, BIL-T= Total bilirubin, ALB= Albumin, LDH=lactate dehydrogenase, Na⁺ = Sodium, K⁺ = potassium, Cl⁻ = Chloride, HCO₃⁻= Total carbon dioxide content %Bias: Mean test- Mean target/Mean target*100, %Bias^d: Bias desirable quality specifications for bias (<https://www.westgard.com/biodatabase1.htm>),%JHH: Percent changes in analyte (Johns Hopkins Hospital Laboratory Acceptability Thresholds),Acceptable criteria and significant limits of clinical limits and/or statistical limits ($p>0.05$)

Table 17 Results of Biochemical Analysis of Plasma Stored in Lithium Heparin Control Tubes and Innomed Tube 1 (Heparin+Antiglycolysis) Using Cobas 758 Automated Analyzer at Maharaj Chiang Mai Hospital, Patient Volunteer Group (n=10)

Test	Control Tube		Test Tube					Acceptable Criteria & Significance		
	Heparin Tube		Innomed Tube 1					Clinical Limit (%)		
	(Commercial Tube)		(Heparin/antiglycolytic agent)					Statistical Limit		
	Range	Mean (SEM)	Range	Mean (SEM)	Bias	Bias ^d	JHH*	<i>P-value</i>		
GLU (mg/dL)	68.9-431.0	129.8 (34.18)	76.4-433.1	133.7 (33.99)	3.00 ⁺	2.34	5	0.937		
ALB (g/dL)	3.6-7.7	4.60 (0.37)	3.59-4.84	4.29 (0.13)	6.74	1.43	7	0.444		
ALP (U/L)	54.0-117.0	84.5 (6.14)	54.0-116.0	84.0 (0.06)	-0.59	6.72	10	0.954		
ALT (U/L)	22.0-70.0	40.8 (5.50)	21.3-69.5	40.1 (5.47)	-1.72	11.48	10	0.927		
AST (U/L)	17.7-46.4	26.5 (2.87)	16.2-47.9	25.9 (3.10)	-2.26	6.54	10	0.894		
BIL-D (mg/dL)	0.16-0.62	0.25 (0.04)	0.16-0.60	0.25 (0.04)	0.00	14.20	5	0.974		
BIL-T (mg/dL)	0.37-1.02	0.56 (0.06)	0.34-1.00	0.055 (0.06)	-1.79	8.95	5	0.956		
BUN (mg/dL)	9.6-55.7	22.3 (4.84)	9.6-55.2	22.3 (4.81)	0.00	5.57	10	0.998		

Test	Control Tube		Test Tube		Acceptable Criteria & Significance			
	Heparin Tube		Innomed Tube 1		Clinical Limit (%)		JHH*	P-value
	Range	Mean (SEM)	Range	Mean (SEM)	Bias	Bias _d [†]		
CHOL (mg/dL)	127.0-252.0	189.4 (14.42)	129.4-248.8	188.4 (14.05)	-0.53	4.10	3	0.959
CRE (mg/dL)	0.68-14.15	3.47 (1.553)	0.68-14.39	3.50 (1.575)	0.86	3.96	8	0.990
HDL (mg/dL)	31.5-58.5	44.5 (2.73)	31.2-58.3	44.2 (2.76)	0.67	5.61	5	0.941
LDH (U/L)	143-371	209 (20.84)	141-373	206 (21.70)	-1.15	4.30	15	0.937
LDL (mg/dL)	61.3-196.6	124.5 (13.65)	61.1-189.5	122.6 (13.12)	-1.53	5.46	5	0.921
TP (g/dL)	7.26-8.54	7.75 (0.13)	7.18-8.40	7.65 (0.14)	-1.29	1.36	7	0.599
TRIG (mg/dL)	41.4-273.1	155.1 (23.49)	41.4-272.6	154.7 (23.79)	-0.26	9.57	10	0.991
UA (mg/dL)	4.3-10.6	6.85 (0.66)	4.2-10.4	6.75 (0.64)	-1.46	4.87	10	0.914
Na ⁺ (mmol/L)	135.2-141.0	139.10 (0.56)	137.9-144.0	141.80 (0.66)	1.94 ⁺	0.23	10	0.005
K ⁺ (mmol/L)	3.3-5.2	4.12	3.3-5.2	4.15	0.73	1.81	5	0.919

Test	Control Tube		Test Tube		Acceptable Criteria & Significance			
	Heparin Tube		Innomed Tube 1		Clinical Limit (%)		JHH*	P-value
	Range	Mean (SEM)	Range	Mean (SEM)	Bias	Bias _d [†]		
Cl ⁻	95.8-108.0	102.20 (1.18)	97.5-109.4	103.90 (1.07)	1.66 ⁺	0.50	5	0.319
HCO ₃ ⁻	24.1-29.2	26.80 (0.52)	24.4-28.4	26.70 (0.49)	-0.37	1.70	10	0.912

Note: SEM = standard error of the mean, %Bias= difference between the compared tube results, Glu =Glucose, BUN =Blood urea nitrogen, CER = Creatinine, CHOL= Total cholesterol, TRIG = Triglyceride, HDL = High-density lipoprotein, LDL = Low-density lipoprotein, UA = Uric acid, AST = Aspartate aminotransferase, ALT = Alanine aminotransferase, ALP = Alkaline phosphatase, BIL-D= Direct bilirubin, BIL-T= Total bilirubin, ALB= Albumin, LDH=lactate dehydrogenase,Na⁺ = Sodium, K⁺ = potassium, Cl⁻ = Chloride, HCO₃⁻= Total carbon dioxide content %Bias: Mean test- Mean target)/Mean target*100, %Bias_d: Bias desirable quality specifications for bias (<https://www.westgard.com/biodatabase1.htm>),%JHH: Percent changes in analyte (Johns Hopkins Hospital Laboratory Acceptability Thresholds),Acceptable criteria and significant limits of clinical limits and/or statistical limits ($p>0.05$)

Table 18 Results of Biochemical Analysis of Plasma Stored in Lithium Heparin Control Tubes and Innomed Tube1 (Heparin+Antiglycolysis) Using Automated Analyzers AU480 and Access II at Koh Samui Hospital, Surat Thani Province, Healthy Volunteer Group (n=10)

Test	Control Tube		Test Tube		Acceptable Criteria & Significance			
	Heparin Tube		Innomed Tube 1					
	(Commercial Tube)		(Heparin/antiglycolytic agent)		Clinical Limit (%)			
	Range	Mean (SEM)	Range	Mean (SEM)	Bias	Bias ^d	JHH*	Statistical Limit <i>P-value</i>
GLU (mg/dL)	91-112	100 (1.80)	87-111	95.9 (2.21)	4.10 ⁺	1.80	8	0.168
ALB (g/dL)	3.36-4.19	3.7 (0.10)	3.37-4.05	3.7 (0.07)	0.00	1.43	7	0.533
ALP (U/L)	36-115	74.8 (7.55)	36-113	72.1 (7.38)	3.61	6.72	10	0.801
ALT (U/L)	8-73	26.8 (6.96)	11-72	28 (6.72)	4.48	11.48	10	0.908
AST (U/L)	16-39	24.4 (2.58)	17-39	24.7 (2.57)	1.23	6.54	10	0.882
BIL-D (mg/dL)	0.25-0.81	0.5 (0.06)	0.24-0.73	0.5 (0.05)	0.00	8.95	10	0.795
BIL-T (mg/dL)	0.06-0.18	0.1 (0.01)	0.05-0.17	0.1 (0.01)	0.00	14.20	NA	0.440
BUN (mg/dL)	7-18	13.5 (1.23)	7-18	13.5 (1.27)	0.00	5.57	10	1.000

Test	Control Tube		Test Tube		Acceptable Criteria & Significance			
	Heparin Tube		Innomed Tube 1					
	(Commercial Tube)		(Heparin/antiglycolytic agent)		Clinical Limit (%)		Statistical Limit	
	Range	Mean (SEM)	Range	Mean (SEM)	Bias	Bias ^{d†}	JHH*	P-value
CHOL (mg/dL)	191-307	237.3 (10.55)	180-297	203.4 (10.25)	2.91	4.10	5	0.645
CRE (mg/dL)	0.59-1.08	0.8 (0.05)	0.56-0.95	0.8 (0.05)	0.00	3.96	7	0.524
HDL (mg/dL)	35-96	62.3 (7.04)	34.92	59.3 (6.76)	4.82	5.16	10	0.764
LDH (U/L)	123-236	169.8 (10.50)	128-238	171.3 (10.33)	0.88	4.30	10	0.920
LDL (mg/dL)	113-194	155.6 (7.92)	114-192	153.8 (7.23)	1.16	5.46	10	0.869
TP (g/dL)	6.3-8	7.2 (0.20)	6.4-7.7	7.2 (0.14)	0.00	1.36	5	0.788
TRIG (mg/dL)	66-188	108.8 (10.63)	63-184	103 (10.94)	5.33	9.57	5	0.708
UA (mg/dL)	2.9-7.1	4.5 (0.42)	2.9-6.5	4.3 (0.38)	4.44	4.87	10	0.848
Na ⁺ (mmol/L)	140-145.2	142.8 (0.52)	145-149.6	147.6 (0.53)	3.36 ⁺	0.23	3	<0.05

Test	Control Tube		Test Tube		Acceptable Criteria & Significance			
	Heparin Tube		Innomed Tube 1					
	(Commercial Tube)		(Heparin/antiglycolytic agent)		Clinical Limit (%)			
	Range	Mean (SEM)	Range	Mean (SEM)	Bias	Bias ^d	JHH*	Statistical Limit
K ⁺	3.43-4.41	3.9 (0.09)	3.47-4.42	3.9 (0.10)	0.00	1.81	5	0.931
Cl ⁻	104-110	107 (0.67)	109-113	110.9 (0.43)	3.64 ⁺	0.50	5	<0.05
HCO ₃ ⁻	21.7-26.7	24.1 (0.47)	20-26.8	24.3 (0.65)	0.83	1.70	15	0.837
TSH	0.66-4.3	2.2 (0.41)	0.64-4.3	2.2 (0.41)	0.00	14.14	NA	0.983
FT3	2.1-3.42	3.0 (0.12)	2.01-3.39	2.9 (0.17)	3.30	4.80	NA	0.847
FT4	0.74-1.51	1.0 (0.08)	0.72-1.42	1.0 (0.17)	0.00	2.98	NA	0.861
T3	69.69-131.93	92.7 (5.16)	71.62-130.89	91.7 (5.06)	1.08	5.19	NA	0.898

Note: SEM = standard error of the mean, %Bias= difference between the compared tube results, Glu =Glucose, BUN = Blood urea nitrogen, CER = Creatinine, CHOL= Total cholesterol, TRIG = Triglyceride, HDL = High-density lipoprotein, LDL = Low-density lipoprotein, UA = Uric acid, AST = Aspartate aminotransferase, ALT = Alanine aminotransferase, ALP = Alkaline phosphatase, BIL-D= Direct bilirubin, BIL-T= Total bilirubin, ALB= Albumin, LDH=lactate dehydrogenase, Na⁺ = Sodium, K⁺ = potassium, Cl⁻ = Chloride,

HCO₃⁻ = Total carbon dioxide, TSH= Thyroid stimulating hormone, FT3= Triiodothyronine, free, FT4= Thyroxine, free, T3= Triiodothyronine, content %Bias: Mean test- Mean target)/Mean target*100, %Bias: Bias desirable quality specifications for bias (<https://www.westgard.com/biodatabase1.htm>), %JHH: Percent changes in analyte (Johns Hopkins Hospital Laboratory Acceptability Thresholds), Acceptable criteria and significant limits of clinical limits and/or statistical limits ($p>0.05$)

Table 19 Results of Biochemical Analysis of Plasma Stored in Lithium Heparin Control Tubes and Innomed Tube 1 (Heparin+Antiglycolysis) Using Automated Analyzers AU480 and Access II at Koh Samui Hospital, Surat Thani Province, Volunteer Patient Group (n=10)

Test	Control Tube Heparin Tube (Commercial Tube)		Test Tube Innomed Tube 1 (Heparin/antiglycolytic agent)		Acceptable Criteria & Significance			
	Range	Mean (SEM)	Range	Mean (SEM)	Clinical Limit (%)		Statistical Limit	<i>P-value</i>
					Bias	Bias ^d		
GLU (mg/dL)	95-316	153.6 (21.35)	87-304	147.4 (20.80)	-4.04	1.8	8	0.838
ALB (g/dL)	2.81-4.12	3.6 (0.16)	22.84-4.09	0.45 (0.16)	0	1.43	7	0.892
ALP (U/L)	0.39-105	72.5 (9.36)	0.42-105	70.7 (9.14)	-2.78	6.72	10	0.892

Test	Control Tube		Test Tube		Acceptable Criteria & Significance				
	Heparin Tube		Innomed Tube 1		(Heparin/antiglycolytic agent)				
	(Commercial Tube)								
	Range	Mean (SEM)	Range	Mean (SEM)	Bias	Bias ^{d†}	JHH*	Clinical Limit (%)	Statistical Limit <i>P-value</i>
ALT (U/L)	6-70	33.9 (7.29)	9-69	35.1 (21.63)	3.54	11.48	10		0.906
AST (U/L)	13-189	54.8 (17)	13-185	54.7 (16.65)	-0.18	6.54	10		0.997
BIL-D (mg/dL)	0.06-0.84	0.4 (0.07)	0.06-0.83	0.4 (0.07)	0	8.95	10		0.929
BIL-T (mg/dL)	0.02-0.26	0.1 (0.02)	0.02-0.25	0.1 (0.02)	0	14.2	-		0.871
BUN (mg/dL)	6-82	22.1 (6.91)	6-81	22.3 (6.80)	0.9	5.57	10		0.984
CHOL (mg/dL)	134-281	214 (15.76)	136-274	208.2 (14.85)	-2.71	4.10	5		0.792
CRE (mg/dL)	0.54-10.6	2.3 (1.19)	0.52-10.31	2.3 (1.16)	0	3.96	7		0.960
HDL (mg/dL)	18-122	10.49 (10.49)	18-144	9.75 (9.75)	-4.8	5.16	10		0.895
LDH (U/L)	157-334	201.7 (18.85)	144-333	200.7 (19.25)	-0.5	4.30	10		0.981

Test	Control Tube		Test Tube		Acceptable Criteria & Significance				
	Heparin Tube (Commercial Tube)		Innomed Tube 1 (Heparin/antiglycolytic agent)						
	Range	Mean (SEM)	Range	Mean (SEM)	Bias	Bias ^d [†]	JHH*	Clinical Limit (%)	Statistical Limit <i>P-value</i>
LDL (mg/dL)	90-209	137.7 (13.82)	85-197	131 (11.86)	-4.87	5.46	10		0.717
TP (g/dL)	6.5-8.6	7.4 (0.20)	6.6-8.5	7.3 (0.16)	-1.35	1.36	5		0.883
TRIG (mg/dL)	89-605	255 (61.67)	84-598	245.4 (59.66)	-3.76	9.57	5		0.912
UA (mg/dL)	2.7-8.1	5.4 (0.65)	2.9-8.1	5.5 (0.65)	1.85	4.87	10		0.991
Na ⁺ (mmol/L)	133.2-147.3	143.2 (1.31)	141-152.7	148.1 (1.09)	3.42 [†]	0.23	3		<0.05
K ⁺ (mmol/L)	3.51-5.81	4 (0.23)	3.58-5.85	0.69 (0.23)	1.81 [†]	0	5		0.951
Cl ⁻ (mmol/L)	99.1-110.8	107.1 (1.16)	105-115.3	111.7 (1.00)	4.3 [†]	0.50	5		<0.05
HCO ₃ ⁻ (mmol/L)	16.2-23.9	20.3 (0.98)	16-24.4	20.5 (1.06)	1.7 [†]	0.99	15		0.880
TSH mIU/mL	0.002-46.03	9.2 (4.51)	0.003-15.82	8.9 (4.46)	-3.26	14.14	NA		0.969

Test	Control Tube		Test Tube		Acceptable Criteria & Significance				
	Heparin Tube		Innomed Tube 1		(Heparin/antiglycolytic agent)				
	(Commercial Tube)								
	Range	Mean (SEM)	Range	Mean (SEM)	Bias	Bias ^{d†}	JHH*	Statistical Limit	P-value
FT3	pg/mL 2.06-10.4	3.4 (0.84)	2.1-1.0	3.4 (0.8)	0.0	4.80	NA	0.999	
FT4	ng/L 0.32-1.75	0.9 (0.15)	0.27-1.74	0.9 (0.15)	0.0	2.89	NA	0.789	
T3	ng/dl 18.23-215.4	75.2 (16.79)	17.6-213	74.8 (16.6)	-0.55	0.19	NA	0.987	

Note: SEM = standard error of the mean, %Bias= difference between the compared tube results, Glu =Glucose, BUN = Blood urea nitrogen,CER = Creatinine, CHOL= Total cholesterol, TRIG = Triglyceride, HDL = High-density lipoprotein, LDL = Low-density lipoprotein, UA = Uric acid, AST = Aspartate aminotransferase, ALT = Alanine aminotransferase, ALP = Alkaline phosphatase, BIL-D= Direct bilirubin, BIL-T= Total bilirubin, ALB= Albumin, LDH=lactate dehydrogenase, Na⁺ = Sodium, K⁺ = potassium, Cl⁻ = Chloride, HCO₃⁻= Total carbon dioxide, TSH= Thyroid stimulating hormone, FT3= Triiodothyronine, free, FT4= Thyroxine, free, T3= Triiodothyronine, content %Bias: Mean test- Mean target)/Mean target*100, %Bias: Bias desirable quality specifications for bias (<https://www.westgard.com/biodatabase1.htm>),%JHH: Percent changes in analyte (Johns Hopkins Hospital Laboratory Acceptability Thresholds),Acceptable criteria and significant limits of clinical limits and/or statistical limits ($p>0.05$)

Table 20 Results of Biochemical Analysis of Plasma Stored in Lithium Heparin Control Tubes and Innomed Tube 1 (Heparin+Antiglycolysis) Using Automated Analyzer Mindray Model CL-6000i at Sukhothai Hospital, Sukhothai Province, Healthy Volunteer Group (n=10)

Test	Control Tube Heparin Tube (Commercial Tube)		Test Tube Innomed Tube 1 (Heparin/antiglycolytic agent)		Acceptable Criteria & Significance				
					Clinical Limit (%)			Statistical Limit	<i>P-value</i>
	Range	Mean (SEM)	Range	Mean (SEM)	Bias	Bias _d [†]	JHH*		
GLU (mg/dL)	81.0-233.0	124.2 (13.79)	88.0-242.0	130.6 (14.33)	5.15 ⁺	2.34	8		0.751
ALB (g/dL)	4.2-4.9	4.56 (0.07)	4.2-4.80	4.57 (0.05)	0.22	1.43	7		0.909
ALP (U/L)	52.0-111.0	69.9 (5.72)	52.0-110.0	69.6 (5.68)	-0.43	6.72	10		0.971
ALT (U/L)	13.0-53.0	26.2 (4.04)	13.0-52.0	25.9 (3.98)	-1.15	11.48	15		0.958
AST (U/L)	14.0-33.0	20.0 (2.13)	15.0-34.0	21.6 (2.30)	8.00	6.54	10		0.615
BIL-D (mg/dL)	0.00-0.30	0.13 (0.03)	0.00-0.30	0.14 (0.03)	7.69	14.20	NA		0.791
BIL-T (mg/dL)	0.30-0.70	0.46 (0.06)	0.20-0.70	0.42 (0.07)	-8.70	8.95	10		0.715
BUN (mg/dL)	10.3-16.1	12.4	10.2-15.9	12.4	0.00	5.57	10		0.989

Test	Control Tube		Test Tube		Acceptable Criteria & Significance				
	Heparin Tube (Commercial Tube)		Innomed Tube 1 (Heparin/antiglycolytic agent)		Clinical Limit (%)			Statistical Limit	<i>P-value</i>
	Range	Mean (SEM)	Range	Mean (SEM)	Bias	Bias _d [†]	JHH*		
CHOL	(mg/dL)	94.0-281.0 207.3 (19.03)	92.0-284.0 205.3 (19.37)	0.85 (0.060)	-0.96	4.10	5		0.942
CRE	(mg/dL)	0.58-1.13 0.86 (0.060)	0.56-1.09 0.85 (0.060)	1.16	3.96	7			0.897
HDL	(mg/dL)	33.0-69.0 51.2 (3.47)	34.0-69.0 51.2 (3.40)	0.00	5.61	10			1.000
LDH	(U/L)	129-242 167 (11.78)	128-245 166 (11.45)	-0.36	4.30	10			0.971
LDL	(mg/dL)	33.0-400.0 145.0 (32.79)	32.0-400.0 144.7 (32.90)	-0.21	5.46	10			0.995
TP	(g/dL)	7.00-8.40 7.71 (0.14)	7.00-8.30 7.66 (0.14)	-0.65	1.36	5			0.804
TRIG	(mg/dL)	80.0-437.0 201.3	74.0-425.0 195.2	-3.03	9.57	5			0.894

Test	Control Tube Heparin Tube (Commercial Tube)		Test Tube Innomed Tube 1 (Heparin/antiglycolytic agent)		Acceptable Criteria & Significance			
	Range	Mean (SEM)	Range	Mean (SEM)	Clinical Limit (%)			Statistical Limit
					Bias	Bias ^{d†}	JHH*	
		(32.1 1)		(31.68)				
UA (mg/dL)	2.9-9.1	6.15 (0.64)	3.0-9.0	6.09 (0.62)	-0.98	4.87	10	0.947
Na ⁺ (mmol/L)	134.0- 142.0	137.8 0 (0.70)	136.0-143.0	140.20 (0.61)	1.74 ⁺	0.23	3	<0.05
K ⁺ (mmol/L)	3.5-4.0	3.77 (0.07)	3.6-4.0	3.82 (0.06)	1.33	1.81	8	0.527
Cl ⁻ (mmol/L)	99.0-105.0	102.7 0 (0.70)	101.0-108.0	105.00 (0.70)	2.24 ⁺	0.50	5	<0.05
HCO ₃ ⁻ (mmol/L)	26.0-29.0	27.70 (0.33)	26.0-31.0	28.70 (0.50)	3.61 ⁺	1.70	15	0.118

Note: SEM = standard error of the mean, %Bias= difference between the compared tube results, Glu =Glucose, BUN = Blood urea nitrogen, CER = Creatinine, CHOL= Total cholesterol, TRIG = Triglyceride, HDL = High-density lipoprotein, LDL = Low-density lipoprotein, UA = Uric acid, AST = Aspartate aminotransferase, ALT = Alanine aminotransferase, ALP = Alkaline phosphatase, BIL-D= Direct bilirubin, BIL-T= Total bilirubin, ALB= Albumin, LDH=lactate dehydrogenase, Na⁺ = Sodium, K⁺ = potassium, Cl⁻ = Chloride, HCO₃⁻= Total carbon dioxide, content %Bias: Mean test- Mean target)/Mean target*100, %Bias_d: Bias desirable quality specifications

for bias (<https://www.westgard.com/biodatabase1.htm>),%JHH: Percent changes in analyte (Johns Hopkins Hospital Laboratory Acceptability Thresholds),Acceptable criteria and significant limits of clinical limits and/or statistical limits ($p>0.05$)

Table 21 Results of Biochemical Analysis of Plasma Stored in Lithium Heparin Control Tubes and Innomed Tube 1 (Heparin+Antiglycolysis) Using Automated Analyzer Mindray Model CL-6000i at Sukhothai Hospital, Sukhothai Province, Patient Volunteer Group (n=10)

Test	Control Tube		Test Tube		Acceptable Criteria & Significance			
	Heparin Tube		Innomed Tube 02					
	(Commercial Tube)		(Heparin/antiglycolytic agent)		Clinical Limit (%)			
	Range	Mean (SEM)	Range	Mean (SEM)	Bias	Bias ^d	JHH*	Statistical Limit
GLU (mg/dL)	87.0-93.0	89.3 (1.44)	91.0-104.0	95.8 (2.87)	7.28 ⁺	2.34	8	0.021
ALB (g/dL)	4.4-4.8	4.60 (0.04)	4.40-4.80	4.63 (0.06)	0.65	1.43	7	0.687
ALP (U/L)	52.0-120.0	73.6 (6.56)	51.0-119.0	73.0 (6.56)	0.82	6.72	10	0.949
ALT (U/L)	8.0-127.0	32.4 (12.22)	8.0-127.0	32.6 (12.19)	0.62	11.48	10	0.991
AST (U/L)	12.0-40.0	19.7 (3.05)	14.0-42.0	20.7 (3.11)	5.08	6.54	10	0.821
BIL-D (mg/dL)	0.10-0.20	0.13 (0.02)	0.10-0.20	0.14 (0.02)	7.69	14.20	5	0.653

Test	Control Tube		Test Tube		Acceptable Criteria & Significance				
	Heparin Tube		Innomed Tube 02		(Heparin/antiglycolytic agent)				
	(Commercial Tube)				Clinical Limit (%)				
	Range	Mean (SEM)	Range	Mean (SEM)	Bias	Bias ^d	JHH*	Statistical Limit	P-value
BIL-T (mg/dL)	0.20-0.70	0.47 (0.05)	0.20-0.60	0.47 (0.04)	0.00	8.95	5	1.000	
BUN (mg/dL)	6.6-15.2	10.5 (0.95)	6.6-15.4	10.6 (0.92)	0.95	5.57	10	0.929	
CHOL (mg/dL)	167.0-285.0	216.1 (11.03)	162.0-277.0	213.2 (10.67)	1.34	4.10	3	0.852	
CRE (mg/dL)	0.58-1.17	0.78 (0.057)	0.57-1.14	0.76 (0.054)	2.56	3.96	8	0.852	
HDL (mg/dL)	45.0-73.0	56.6 (3.06)	44.0-72.0	56.4 (3.03)	0.35	5.61	5	0.963	
LDH (U/L)	130-201	163 (8.04)	132-205	166 (7.63)	2.27	4.30	15	0.949	
LDL (mg/dL)	91.0-206.0	128.1 (12.16)	88.0-199.0	127.0 (11.72)	-0.86	5.46	5	0.949	
TP (g/dL)	7.00-8.60	7.92 (0.16)	7.00-8.70	7.89 (0.16)	-0.38	1.36	7	0.896	
TRIG (mg/dL)	45.0-225.0	157.1 (18.16)	39.0-214.0	148.9 (17.98)	-5.22	9.57	10	0.752	
UA (mg/dL)	2.9-7.8	5.23 (0.51)	2.7-7.8	5.25 (0.52)	0.38	4.87	10	0.978	

Test	Control Tube		Test Tube		Acceptable Criteria & Significance			
	Heparin Tube		Innomed Tube 02		(Heparin/antiglycolytic agent)			
	(Commercial Tube)				Clinical Limit (%)			
	Range	Mean (SEM)	Range	Mean (SEM)	Bias	Bias ^d	JHH*	P-value
Na ⁺ (mmol/L)	135.0-141.0	137.40 (0.56)	137.0-144.0	139.80 (0.71)	1.75 ⁺	0.23	10	0.017
K ⁺ (mmol/L)	3.4-4.1	3.76 (0.09)	3.5-4.2	3.82 (0.08)	1.60	1.81	5	0.731
Cl ⁻ (mmol/L)	101.0-106.0	103.70 (0.54)	103.0-109.0	106.30 (0.65)	2.51 ⁺	0.50	5	0.007
HCO ₃ ⁻ (mmol/L)	23.0-29.0	26.70 (0.58)	25.0-30.0	27.50 (0.58)	3.00 ⁺	1.70	10	0.343

Note: SEM = standard error of the mean, %Bias= difference between the compared tube results, Glu =Glucose, BUN = Blood urea nitrogen, CER = Creatinine, CHOL= Total cholesterol, TRIG = Triglyceride, HDL = High-density lipoprotein, LDL = Low-density lipoprotein, UA = Uric acid, AST = Aspartate aminotransferase, ALT = Alanine aminotransferase, ALP = Alkaline phosphatase, BIL-D= Direct bilirubin, BIL-T= Total bilirubin, ALB= Albumin, LDH=lactate dehydrogenase, Na⁺ = Sodium, K⁺ = potassium, Cl⁻= Chloride, HCO₃⁻= Total carbon dioxide, content %Bias: Mean test- Mean target)/Mean target*100, %Bias_d: Bias desirable quality specifications for bias (https://www.westgard.com/biobase1.htm),%JHH: Percent changes in analyte (Johns Hopkins Hospital Laboratory Acceptability Thresholds),Acceptable criteria and significant limits of clinical limits and/or statistical limits ($p>0.05$)

Table 22 Results of Biochemical Analysis of Plasma Stored in Lithium Heparin Control Tubes and Innomed Tube Model 02 (Heparin+Antiglycolysis) Using Automated Analyzer Beckman Coulter at Phutthachinnarat Hospital, Phitsanulok Province, Healthy Volunteer Group (n=10)

Test	Control Tube Heparin Tube (Commercial Tube)			Test Tube Innomed Tube 02 (Heparin/antiglycolytic agent)			Acceptable Criteria & Significance			
	Heparin Tube (Commercial Tube)			Innomed Tube 02 (Heparin/antiglycolytic agent)			Clinical Limit (%)		Statistical Limit	<i>P-value</i>
	Range	Mean (SEM)	Range	Mean (SEM)	Bias	Bias ^d [†]	JHH*			
GLU (mg/dL)	81-89	86 (1.89)	91-97	93 (1.44)	8 ⁺	1.80	8		0.026	
ALP (U/L)	43-85	60.6 (7.42)	40-83	58 (7.27)	4.29	6.72	10		0.806	
ALT (U/L)	10-38	19.8 (5.18)	7-38	18.2 (5.55)	8.08	11.48	10		0.838	
AST (U/L)	17-22	19.6 (0.87)	18-22	19.8 (0.73)	1.02	6.54	10		0.867	
BUN (mg/dL)	7-14	10.8 (1.39)	7-15	11.2 (1.46)	3.7	5.57	10		0.848	
CHOL (mg/dL)	187-216	202 (5.03)	180-210	194 (5.78)	3.76	4.10	5		0.350	
CRE (mg/dL)	0.56-1.02	0.8 (0.09)	0.55-1.02	0.8 (0.09)	0.0	3.96	7		0.375	

Test	Control Tube		Test Tube		Acceptable Criteria & Significance			
	Heparin Tube (Commercial Tube)		Innomed Tube 02 (Heparin/antiglycolytic agent)		Clinical Limit (%)		Statistical Limit	<i>P-value</i>
	Range	Mean (SEM)	Range	Mean (SEM)	Bias	Bias _d [†]	JHH*	
HDL	(mg/dL) 32-68	54.8 (8.42)	31-66	52.3 (7.74)	4.56	5.16	10	0.834
LDL	(mg/dL) 104-150	129 (8.81)	102-153	125 (9.87)	3.10	5.46	10	0.770
TRIG	(mg/dL) 74-133	99 (13.94)	70-129	95.2 (13.67)	3.84	9.57	5	0.851
UA	(mg/dL) 2.6-7.8	5.7 (0.86)	2.6-7.8	5.8 (0.88)	1.75	4.87	10	0.956
FT3	pg/mL 0.30-0.37	0.3 (0.04)	0.29-0.37	0.3 (0.04)	0.00	4.80	NA	0.934
FT4	ng/L 0.78-0.93	0.9 (0.08)	0.91-0.93	0.9 (0.01)	0.00	2.98	NA	0.548
Ca	mg/dL 8.5-8.9	8.7 (0.20)	8.7-8.8	8.8 (0.05)	1.15	0.82	5	0.849
Mg	mg/dL 3.7-3.9	3.8 (0.10)	3.4-3.8	3.6 (0.20)	5.26	1.8	10	0.535
Phos	mg/dL 3.7-3.9	3.8 (0.10)	3.4-3.8	3.6 (0.20)	5.26	NA	8	0.535
PSA	ng/mL 0.49-0.95	0.8 (0.14)	0.58-1.10	0.9 (0.17)	12.5	18.7	-	0.578

Test	Control Tube		Test Tube		Acceptable Criteria & Significance			
	Heparin Tube (Commercial Tube)		Innomed Tube 02 (Heparin/antiglycolytic agent)		Clinical Limit (%)		Statistical Limit	
	Range	Mean (SEM)	Range	Mean (SEM)	Bias	Bias _d [†]	JHH*	P-value
CEA	ng/dL 0.6-2.1	1.1 (0.48)	0.7-1.8	1.1 (0.35)	0.00	14.3	-	0.958

Note: SEM = standard error of the mean, %Bias= difference between the compared tube results, Glu =Glucose, BUN = Blood urea nitrogen, CER = Creatinine, CHOL= Total cholesterol, TRIG = Triglyceride, HDL = High-density lipoprotein, LDL = Low-density lipoprotein, UA = Uric acid, AST = Aspartate aminotransferase, ALT = Alanine aminotransferase, ALP = Alkaline phosphatase, BIL-D= Direct bilirubin, BIL-T= Total bilirubin, ALB= Albumin, LDH=lactate dehydrogenase, Na+ = Sodium, K+ = potassium, Cl- = Chloride, HCO3-= Total carbon dioxide, Ca= Calcium, Mg= Magnesium, Phos= Phosphorus, PSA= Prostatic specific antigen, CEA= Carcinoembryonic antigen, content %Bias: Mean test- Mean target)/Mean target*100, %Biasd: Bias desirable quality specifications for bias (https://www.westgard.com/biodatabase1.htm),%JHH: Percent changes in analyte (Johns Hopkins Hospital Laboratory Acceptability Thresholds),Acceptable criteria and significant limits of clinical limits and/or statistical limits (p>0.05)

Table 23 Results of Biochemical Analysis of Plasma Stored in Lithium Heparin Control Tubes and Innomed Tube1 (Heparin + Antiglycolysis) Using Beckman Coulter Automated Analyzer at Phuthachinnarat Hospital, Phitsanulok Province, Volunteer Patient Group (n=10)

Test	Control Tube		Test Tube		Acceptable Criteria & Significance			
	Heparin Tube (Commercial Tube)		Innomed Tube 02 (Heparin/antiglycolytic agent)		Clinical Limit (%)		Statistical Limit	<i>P-value</i>
	Range	Mean (SEM)	Range	Mean (SEM)	Bias	Bias [†]	JHH*	
GLU (mg/dL)	89-167	112.4 (13.95)	93-169	117.2 (13.43)	4.27 ⁺	1.8	8	0.810
ALP (U/L)	28-82	50.2 (9.47)	27-87	50.6 (10.65)	0.80	6.72	10	0.978
ALT (U/L)	7-25	12.4 (3.49)	7-21	11.2 (2.52)	9.68	11.48	10	0.788
AST (U/L)	15-24	18.2 (1.56)	15-25	18.6 (1.81)	2.20	6.54	10	0.871
BUN (mg/dL)	7-13	11 (1.05)	7-12	10.8 (0.97)	1.82	5.57	10	0.892
CHOL (mg/dL)	171-228	199 (9.11)	171-227	199 (8.94)	0.10	4.10	5	0.988
CRE (mg/dL)	0.71- 0.84	0.8 (0.02)	0.72-0.81	0.8 (0.02)	0.00	3.36	7	0.546
HDL (mg/dL)	44-89	63.8 (8.05)	44-88	63.8 (8.06)	0.00	5.16	10	1.000

LDL	(mg/dL)	96-128	116 (6.20)	96-128	116 (5.63)	0.17	5.46	10	0.982
TRIG	(mg/dL)	55-150	96 (18.94)	55-144	94 (18.22)	2.49	9.57	5	0.929
UA	(mg/dL)	4.4-6.1	5 (0.30)	4.3-5.8	4.9 (0.26)	2.00	4.87	10	0.818

Note: SEM = standard error of the mean, %Bias= difference between the compared tube results, Glu =Glucose, BUN = Blood urea nitrogen, CER = Creatinine, CHOL= Total cholesterol, TRIG= Triglyceride, HDL = High-density lipoprotein, LDL = Low-density lipoprotein, UA = Uric acid, AST = Aspartate aminotransferase, ALT = Alanine aminotransferase, ALP = Alkaline phosphatase, BIL-D= Direct bilirubin, BIL-T= Total bilirubin, ALB= Albumin, LDH=lactate dehydrogenase, content %Bias: Mean test- Mean target)/Mean target* 100, %Bias: Bias desirable quality specifications for bias (<https://www.westgard.com/biodatabase1.htm>),%JHH: Percent changes in analyte (Johns Hopkins Hospital Laboratory Acceptability Thresholds),Acceptable criteria and significant limits of clinical limits and/or statistical limits ($p>0.05$)

Innomed Tube Formula 2 (Clot Activator + Antiglycolysis)

Blood Glucose Level Monitoring:

The results of glucose level monitoring showed that glucose levels could be managed effectively within 0 hours (within 45 minutes after blood collection) from the start. When compared to the reference tubes containing Sodium Fluoride (NaF) and Clot Activator, meeting the acceptance criteria of at least 1 criterion, it was found that the average values met the statistically significant limits with a 95% confidence level and a p-value > 0.005 , as per the accepted criteria.

Tumor Markers:

The results of the tumor marker tests for Carcinoembryonic Antigen (CEA) and Prostate-Specific Antigen (TPSA) were compared to the reference tubes containing Clot Activator. Meeting the acceptance criteria of at least 1 criterion, it was found that the average values met the statistically significant limits with a 95% confidence level and a p-value > 0.05 . The bias percentage was less than the specified bias percentage (Bias_d), with CEA and TPSA having bias percentages of 14.3% and 18.7%, respectively.

Thyroid Hormones:

The results of the thyroid hormone tests including Thyroid Stimulating Hormone (TSH), Free Triiodothyronine (FreeT3), and Free Thyroxine (FreeT4) were compared to the reference tubes containing Clot Activator. Meeting the acceptance criteria of at least 1 criterion, it was found that the average values of TSH, FreeT3, and FreeT4 met the statistically significant limits with a 95% confidence level and a p-value > 0.05 . The bias percentage was less than the specified bias percentage (Bias_d), with TSH, FreeT3, and FreeT4 having bias percentages of 7.80%, 4.80%, and 3.30%, respectively.

Biochemical Analysis:

The results of 20 clinical chemistry tests including including GLU, CHOL, TG, HDL, LDL, BUN, CRE, UA, AST, ALT, ALP, TBIL, DBIL, Globulin, ALB, TP, LDH, Na⁺, K⁺, Cl⁻, and HCO₃⁻ were compared to the reference tubes containing Clot Activator. Meeting the acceptance criteria of at least 1 criterion, it was found that the majority of the tested analytes had average values meeting the statistically significant limits with a 95% confidence level and p-value > 0.05 . Additionally, the bias percentage of the mean value was less than the specified bias percentage (Bias_d), except for LDH, Na⁺, K⁺, Cl⁻, and HCO₃⁻. For these analytes, the average bias percentage was less than the bias percentage specified by the JHH criteria.

Table 24 Results of Biochemical Analysis of Plasma Samples Collected in Clot Activator Control Tubes and Innomed Tube 2 (Clot Activator + Antiglycolysis) Blood Collection Tubes Using the Automated Analyzer Cobas 758 at Maharaj Nakorn Chiang Mai Hospital, Healthy Volunteer Group (n=10)

Test	Control Tube		Test Tube		Acceptable Criteria & Significance				
	Clot activator Tube (Commercial Tube)		Innomed Tube 2 (Clot activator +Antiglycolysis)		Clinical Limit (%)			JHH*	P-value
	Range	Mean (SEM)	Range	Mean (SEM)	Bias	Biasd [†]			
GLU (mg/dL)	77.4-105.9	88.6 (2.78)	86.2-107.0	93.9 (2.02)	5.98 [†]	2.34	8		0.149
ALB (g/dL)	4.1-4.7	4.55 (0.06)	4.09-4.65	4.47 (0.05)	1.76	1.43	7		0.283
ALP (U/L)	58.0-105.0	75.6 (4.77)	57.0-103.0	74.9 (4.77)	0.93	6.72	10		0.918
ALT (U/L)	9.8-49.2	22.8 (4.38)	9.7-51.3	22.8 (4.52)	0.00	11.48	10		0.992
AST (U/L)	6.5-33.2	15.0 (2.34)	6.6-35.1	15.3 (2.48)	2.00	6.54	10		0.938
BIL-D (mg/dL)	0.09-0.36	0.20 (0.03)	0.10-0.36	0.19 (0.03)	5.00	14.20	5		0.775
BIL-T (mg/dL)	0.19-0.82	0.50 (0.07)	0.19-0.81	0.50 (0.07)	0.00	8.95	5		1.000

Test	Control Tube		Test Tube		Acceptable Criteria & Significance				
	Clot activator Tube (Commercial Tube)		Innomed Tube 2 (Clot activator +Antiglycolysis)		Clinical Limit (%)			Statistical Limit	
	Range	Mean (SEM)	Range	Mean (SEM)	Bias	Bias ^d	JHH*	<i>P-value</i>	
BUN (mg/dL)	6.6-18.9	13.0 (1.31)	6.4-19.0	13.0 (1.32)	0.00	5.57	10	0.975	
CHOL (mg/dL)	172.3-258.0	199.9 (10.09)	170.0-252.0	196.5 (9.76)	1.70	4.10	3	0.809	
CRE (mg/dL)	0.59-0.96	0.73 (0.044)	0.55-0.99	0.70 (0.038)	4.11 ⁺	3.96	8	0.639	
HDL (mg/dL)	44.4-73.3	54.7 (2.92)	40.9-71.6	53.6 (2.99)	2.01	5.61	5	0.802	
LDH (U/L)	99-204	156 (8.81)	108-210	157 (10.13)	1.16	4.30	15	0.895	
LDL (mg/dL)	97.7-176.9	126.4 (8.65)	96.4-173.0	125.2 (8.55)	-0.95	5.46	5	0.922	
TP (g/dL)	7.12-7.98	7.63 (0.08)	7.04-7.97	7.58 (0.08)	-0.66	1.36	7	0.645	
TRIG (mg/dL)	57.0-213.3	125.6 (15.14)	54.9-209.9	124.3 (15.03)	-1.04	9.57	10	0.953	
UA (mg/dL)	4.9-8.8	6.10 (0.37)	4.8-8.8	6.04 (0.37)	-0.98	4.87	10	0.909	

Test	Control Tube		Test Tube		Acceptable Criteria & Significance			
	Clot activator Tube (Commercial Tube)		Innomed Tube 2 (Clot activator +Antiglycolysis)		Clinical Limit (%)			Statistical Limit
	Range	Mean (SEM)	Range	Mean (SEM)	Bias	Bias ^d	JHH*	
Na⁺	(mmol/L) 136.4-141.8	139.30 (0.58)	139.0-143.6	141.50 (0.52)	1.58 ⁺	0.23	10	0.009
K⁺	(mmol/L) 3.8-4.6	4.13 (0.06)	3.8-4.7	4.20 (0.08)	1.69	1.81	5	0.481
Cl⁻	(mmol/L) 99.9-104.0	102.70 (0.41)	103.2-106.7	104.60 (0.38)	1.85 ⁺	0.50	5	0.003
HCO₃⁻	(mmol/L) 21.0-26.5	24.00 (0.58)	21.4-27.3	24.70 (0.62)	2.92 ⁺	1.70	10	0.421

Note: SEM = standard error of the mean, %Bias= difference between the compared tube results, Glu =Glucose, BUN = Blood urea nitrogen,CER = Creatinine, CHOL= Total cholesterol, TRIG = Triglyceride, HDL = High-density lipoprotein, LDL = Low-density lipoprotein, UA = Uric acid, AST = Aspartate aminotransferase, ALT = Alanine aminotransferase, ALP = Alkaline phosphatase, BIL-D= Direct bilirubin, BIL-T= Total bilirubin, ALB= Albumin, LDH=lactate dehydrogenase, Na⁺ = Sodium, K⁺ = potassium, Cl⁻ = Chloride, HCO₃⁻= Total carbon dioxide content %Bias: Mean test- Mean target)/Mean target*100, %Bias^d: Bias desirable quality specifications for bias (<https://www.westgard.com/biodatabase1.htm>), %JHH: Percent changes in analyte (Johns Hopkins Hospital Laboratory Acceptability Thresholds),Acceptable criteria and significant limits of clinical limits and/or statistical limits ($p>0.05$)

Table 25 Results of Biochemical Analysis of Plasma Samples Collected in Clot Activator Control Tubes and Innomed Tube 2 (Clot Activator + Antiglycolysis) Blood Collection Tubes Using the Automated Analyzer Cobas 758 at Maharaj Nakorn Chiang Mai Hospital, Patient Volunteer Group (n=10)

Test	Control Tube		Test Tube		Acceptable Criteria & Significance			
	Clot activator Tube (Commercial Tube)		Innomed Tube 2 (Clot activator +Antiglycolysis)		Clinical Limit (%)			Statistical Limit
	Range	Mean (SEM)	Range	Mean (SEM)	Bias	Bias ^d [†]	JHH*	P-value
GLU (mg/dL)	68.9- 431.0	129.8 (34.18)	76.4-433.1	133.7 (33.99)	3.00 [†]	2.34	5	0.937
ALB (g/dL)	3.6-4.9	4.32 (0.14)	3.59-4.84	4.29 (0.13)	-0.69	1.43	7	0.444
ALP (U/L)	54.0- 117.0	84.5 (6.14)	54.0-116.0	84.0 (6.06)	-0.59	6.72	10	0.954
ALT (U/L)	22.0-70.0	40.8 (5.50)	21.3-69.5	40.1 (5.47)	-1.72	11.48	10	0.927
AST (U/L)	17.7-46.4	26.5 (2.87)	16.2-47.9	25.9 (3.10)	-2.26	6.54	10	0.894
BIL-D (mg/dL)	0.16-0.62	0.25 (0.04)	0.16-0.60	0.25 (0.04)	0.00	14.20	5	0.974
BIL-T (mg/dL)	0.37-1.02	0.56 (0.06)	0.34-1.00	0.55 (0.06)	-1.79	8.95	5	0.956

Test	Control Tube		Test Tube		Acceptable Criteria & Significance			
	Clot activator Tube (Commercial Tube)		Innomed Tube 2 (Clot activator +Antiglycolysis)		Clinical Limit (%)			Statistical Limit
	Range	Mean (SEM)	Range	Mean (SEM)	Bias	Bias ^d [†]	JHH [*]	
BUN	(mg/dL)	9.6-55.7	22.3 (4.84)	22.3 (4.81)	0.00	5.57	10	0.998
CHOL	(mg/dL)	127.0- 252.0	189.4 (14.42)	129.4- 248.8 (14.05)	-0.53	4.10	3	0.959
CRE	(mg/dL)	0.68- 14.15	3.47 (1.553)	0.68-14.39 (1.575)	0.86	3.96	8	0.990
HDL	(mg/dL)	0.68- 14.15	3.47 (2.73)	31.2-58.3 (2.76)	0.67	5.61	5	0.941
LDH	(U/L)	31.5-58.5	44.5 (20.84)	141-373 (21.70)	-1.15	4.30	15	0.937
LDL	(mg/dL)	143-371	209 (13.65)	61.1-189.5 (13.12)	-1.53	5.46	5	0.921
TP	(g/dL)	61.3- 196.6	124.5 (0.13)	7.188.40 (0.14)	-1.29	1.36	7	0.599
TRIG	(mg/dL)	7.26-8.54	7.75 (23.49)	41.1-272.6 (23.79)	-0.26	9.57	10	0.991
UA	(mg/dL)	41.4- 273.1	155.1 (0.66)	4.2-10.4 (0.64)	-1.46	4.87	10	0.914

Test	Control Tube		Test Tube		Acceptable Criteria & Significance		
	Clot activator Tube (Commercial Tube)		Innomed Tube 2 (Clot activator +Antiglycolysis)		Clinical Limit (%)		Statistical Limit
	Range	Mean (SEM)	Range	Mean (SEM)	Bias	Bias ^d	JHH* <i>P-value</i>
Na⁺	(mmol/L) 4.3-10.6	6.85 (0.56)	137.9- 144.0	141.80 (0.66)	1.94 ⁺	0.23	10 0.005
K⁺	(mmol/L) 135.2- 141.0	139.10 (0.18)	3.3-5.2	4.15 (0.17)	0.73	1.81	5 0.919
Cl⁻	(mmol/L) 95.8- 108.0	102.20 (1.18)	97.5-109.4	103.90 (1.07)	1.66 ⁺	0.50	5 0.319
HCO₃⁻	(mmol/L) 24.1-29.2	26.80 (0.52)	24.4-28.4	26.70 (0.49)	-0.37	1.70	10 0.912

Note: SEM = standard error of the mean, %Bias= difference between the compared tube results, Glu =Glucose, BUN = Blood urea nitrogen, CER = Creatinine, CHOL= Total cholesterol, TRIG = Triglyceride, HDL = High-density lipoprotein, LDL = Low-density lipoprotein, UA = Uric acid, AST = Aspartate aminotransferase, ALT = Alanine aminotransferase, ALP = Alkaline phosphatase, BIL-D= Direct bilirubin, BIL-T= Total bilirubin, ALB= Albumin, LDH=lactate dehydrogenase, Na⁺ = Sodium, K⁺ = potassium, Cl⁻ = Chloride, HCO₃⁻= Total carbon dioxide content %Bias: Mean test- Mean target)/Mean target*100, %Biasa: Bias desirable quality specifications for bias (<https://www.westgard.com/biodatabase1.htm>), %JHH: Percent changes in analyte (Johns Hopkins Hospital Laboratory Acceptability Thresholds),Acceptable criteria and significant limits of clinical limits and/or statistical limits ($p>0.05$)

Table 26 Results of Thyroid Hormones Analysis in Plasma Samples Collected in Clot Activator Control Tubes and Innomed Tube 2 (Clot Activator + Antiglycolysis) Blood Collection Tubes Using the Automated Analyzer Mindray BS2000 at Sukhothai Hospital, Healthy Volunteer Group (n=10).

Test	Control Tube		Test Tube		Acceptable Criteria & Significance			
	Clot activator Tube (Commercial Tube)		Innomed Tube 2 (Clot activator +Antiglycolysis)		Clinical Limit (%)		Statistical Limit	
	Range	Mean (SEM)	Range	Mean (SEM)	Bias	Bias _d [†]	JHH*	P-value
TSH mIU/mL	0.69-2.37	1.30 (0.18)	0.67-2.33	1.30 (0.17)	0.00	14.14	NA	0.924
FT3 pg/mL	2.63-3.70	3.20 (0.12)	2.71-3.62	3.20 (0.10)	2.60	4.80	NA	0.864
FT4 ng/L	7.06-11.67	9.61 (0.47)	7.02-13.11	9.86 (0.58)	0.00	2.60	NA	0.736

Note: SEM = standard error of the mean, %Bias= difference between the compared tube results , TSH = Thyroid stimulating hormone, FT3 = Triiodothyronine, free, FT4 = Thyroxine, free %Bias: Mean test- Mean target)/Mean target*100, %Bias_d: Bias desirable quality specifications for bias (<https://www.westgard.com/biodatabase1.htm>), %JHH: Percent changes in analyte (Johns Hopkins Hospital Laboratory Acceptability Thresholds), Acceptable criteria and significant limits of clinical limits and/or statistical limits ($p>0.05$)

Table 27 Results of Thyroid Hormones Analysis in Plasma Samples Collected in Clot Activator Control Tubes and Innomed Tube 2 (Clot Activator + Antiglycolysis) Blood Collection Tubes Using the Automated Analyzer Mindray BS2000 at Sukhothai Hospital, Patient Volunteer Group (n=10).

Test	Control Tube		Test Tube		Acceptable Criteria & Significance			
	Clot activator Tube (Commercial Tube)		Innomed Tube 2 (Clot activator +Antiglycolysis)		Clinical Limit (%)		Statistical Limit	<i>P-value</i>
	Range	Mean (SEM)	Range	Mean (SEM)	Bias	Bias ^{d†}	JHH*	
TSH mIU/mL	0.91-3.14	1.50 (0.21)	0.93-3.14	1.50 (0.21)	0.00	14.14	NA	0.959
FT3 pg/mL	2.72-3.71	3.30 (0.12)	2.73-3.81	3.30 (0.14)	0.00	4.80	NA	0.678
FT4 ng/L	6.78-11.48	9.53 (0.48)	6.25-12.21	10.00 (0.61)	2.98	2.60	NA	0.555

Note: SEM = standard error of the mean, %Bias= difference between the compared tube results , TSH = Thyroid stimulating hormone, FT3 = Triiodothyronine, free, FT4 = Thyroxine, free %Bias: Mean test- Mean target)/Mean target*100, %Bias_d: Bias desirable quality specifications for bias (<https://www.westgard.com/biodatabase1.htm>), %JHH: Percent changes in analyte (Johns Hopkins Hospital Laboratory Acceptability Thresholds), Acceptable criteria and significant limits of clinical limits and/or statistical limits ($p>0.05$)

Discussion

The clinical evaluation of Innomed Blood Collection Tube Formula 1 (Heparin/antiglycolytic agent) was conducted in accordance with the CLSI GP34-A standard for validating and verifying tubes for venous and capillary blood specimen collection. The study involved the collection of blood from volunteer donors using the formulated tubes. The physical observations demonstrated that the tubes effectively prevented red blood cell lysis, fibrin formation, and clotting. Glucose levels, biochemical parameters, tumor markers, thyroid hormones, complete blood count (CBC), and hemoglobin A1c (HbA1c) were analyzed within the specified timeframe. The evaluation revealed that the average glucose levels in Innomed Tubes formula 1 remained well within acceptable limits compared to reference tubes coated with sodium fluoride (NaF) during the initial 8 hours. Statistical analysis indicated no significant difference at a 95% confidence level, with a p-value of 0.742. A decrease of 7.62% in mean glucose value was observed after 8 hours, remaining within the acceptable limit of a 10% reduction. The % Bias of the average glucose level at the start time was 1.03%, which was below the desirable % Biasd value of 2.34%. Comparison of HbA1c results with K3EDTA reference tubes demonstrated compliance with at least one criterion as per accepted standards. The mean HbA1c values showed no significant difference ($p > 0.05$), and the % Bias was 0.00%, lower than the desirable % Biasd value of 1.7%. In the case of CBC results, the evaluation compared to K3EDTA reference tubes met standards for at least one criterion. Except for a statistically significant reduction in blood cell count, the mean CBC values did not exhibit significant differences ($p > 0.05$) at the 95% confidence level. The evaluation of Thyroid-Stimulating Hormone (TSH) results compared to lithium heparin reference tubes fulfilled at least one criterion based on accepted standards. The mean TSH values showed no significant difference ($p > 0.05$), and the % Bias was 7.80%, lower than the desirable % Biasd value. For the assessment of tumor markers, such as Carcinoembryonic Antigen (CEA), Innomed tubes formula 1 met at least one criterion compared to lithium heparin reference tubes. The mean CEA values demonstrated no significant difference ($p > 0.05$), with % Bias values of 14.3% and 18.7%, both below the desirable % Biasd values. Biochemical analysis involving 15 parameters showed that the results obtained using the newly formulated coating aligned well with acceptable limits at a 95% confidence level. Most parameters exhibited p-values > 0.05 and/or % Bias values lower than the desirable % Biasd and JHH values as specified in the standard.

Innomed Blood Collection Tube Formula 2 underwent a similar clinical evaluation process. The formulated Clot activator/antiglycolytic agent tubes effectively prevented red blood cell lysis, fibrin formation, and clotting. Analysis of glucose levels, biochemical parameters, tumor markers, and thyroid hormones demonstrated that the average glucose levels within Innomed tubes formula 2 remained acceptable compared to sodium fluoride (NaF) reference tubes for up to 8 hours. Statistical analysis indicated no significant difference at a 95% confidence level ($p\text{-value} = 0.833$). A decrease of 5.9% in mean glucose value was observed after 8 hours, well within the acceptable limit of a 10% reduction. Additionally, the % Bias of the average glucose level at the start time decreased by -1.09%, lower than the desirable % Biasd value of 2.34%. Similar to the findings for formula 1, TSH results in formula 2 compared to reference and control

tubes met at least one criterion based on accepted standards. Mean TSH values showed no significant difference ($p > 0.05$), and the % Bias was 7.80%, lower than the desirable % Biasd value. The evaluation of CEA, a tumor marker, exhibited results that met at least one criterion compared to reference and control tubes. Mean CEA values showed no significant difference ($p > 0.05$), with a % Bias of 14.3%, lower than the desirable % Biasd value. The biochemical analysis for formula 2, encompassing 15 parameters, yielded results well within acceptable limits at a 95% confidence level. Parameters generally displayed p-values > 0.05 and/or % Bias values lower than the desirable % Biasd and JHH values specified in the standard.

In conclusion, both Innomed Blood Collection Tube Formula 1 and Formula 2 underwent comprehensive clinical evaluations following established standards. The tubes effectively prevented hemolysis, fibrin formation, and clotting within the specified timeframe. Results for glucose levels.

Study 2. Impact of Centrifugation Time on Biochemical Measurement Values

The study investigated the effects of different centrifugation times (5 minutes and 10 minutes) on lactate dehydrogenase (LDH) levels in Innomed blood collection tubes, formulas 1 and 2. The results indicated that neither formula exhibited statistically significant differences in LDH levels between the two centrifugation times. This suggests that the choice of a 5-minute or 10-minute centrifugation time may not significantly impact LDH measurements in Innomed blood collection tubes for both formulas.

Study 3. Effects of Blood Collection Techniques on Biochemical Analysis

For Innomed Blood Collection Tube formula 1, blood collected via both the needle-syringe and vacuum extraction systems yielded comparable LDH levels. The % Bias values for both techniques were low, with no significant statistical differences compared to the Heparin tube. A % Bias of 4.3% was observed when comparing the two techniques.

Similar findings were observed for Innomed Blood Collection Tube formula 2. The % Bias values for LDH measurements using the needle-syringe and vacuum extraction systems were also low, and no significant statistical differences were observed compared to the Clot activator tube. The % Bias between results from Innomed tube formula 2 and the Clot activator tube was 0.831%.

In both cases, the study concluded that the choice of blood collection technique did not result in statistically significant differences in LDH levels within the Innomed blood collection tubes. The low % Bias values and non-significant P-values suggested that the selection of blood collection technique may not significantly impact LDH measurements for both formulas.

Study 4. Effects of Storage Time on RBC Hemolysis

Both formula 1 and formula 2 of Innomed blood collection tubes underwent evaluation with varying storage times (0 hours and 24 hours). The LDH levels were affected by storage time for both formulas. The % Bias values indicated statistically significant differences in LDH levels between the two storage time points for both formulas. These findings suggest that longer storage times lead to changes in LDH levels within Innomed blood collection tubes.

Study 5. Validation of Blood Collection Tubes through Multicenter Study

The assessment of Innomed Tube Formula 1 and 2 across multiple hospitals showed favorable results for various biochemical measurements. Blood glucose level monitoring, hemoglobin measurements, tumor marker evaluations, thyroid hormone analyses, and biochemical parameter assessments aligned well with reference tubes. The mean values for most analytes were statistically significant, with % Bias values meeting the acceptable thresholds. Some analytes exhibited slight biases below acceptable levels when evaluated against specific criteria.



CHAPTER V

CONCLUSIONS

This study clinically evaluated two newly developed Innomed Vacuum Blood Collection Tubes in accordance with the CLSI GP34-A guideline for validation and verification of venous blood specimen collection tubes. The findings demonstrated that both formulations provided acceptable analytical performance and were suitable for routine clinical laboratory use.

Innomed Formula 1, containing lithium heparin with antiglycolytic agents, showed satisfactory agreement with reference tubes for glucose, routine biochemical analytes, HbA1c, thyroid hormone testing, tumor marker assays, and most complete blood count parameters. Formula 2, containing clot activator with antiglycolytic agents, also demonstrated acceptable comparability with reference tubes for glucose preservation, biochemical analyses, thyroid function tests, and tumor marker measurements.

Both Innomed tube formulations effectively maintained blood glucose stability for up to 8 hours after collection, with glucose reduction remaining within acceptable clinical limits. This indicates their usefulness in situations where specimen transport or delayed processing may occur, particularly in diabetes screening and chronic disease monitoring programs.

No clinically significant hemolysis was observed under the evaluated blood collection techniques, centrifugation conditions, or storage periods, indicating that the tubes possess adequate physical and analytical robustness during routine pre-analytical handling.

The multicenter validation approach further supported the applicability of Innomed tubes across different hospital laboratories and analyzer platforms, suggesting that these tubes can be implemented in diverse clinical settings with reliable performance.

In conclusion, Innomed vacuum blood collection tubes are suitable alternative blood collection devices for clinical laboratory testing. Their ability to preserve glucose, support multiple laboratory assays, and maintain specimen quality may reduce dependence on imported products and contribute to strengthening domestic medical device innovation and laboratory service capacity.



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