CT RENAL VOLUMETRY AND CONTRAST-INDUCED NEPHROPATHY IN PRE-CHEMOTHERAPY NON-RENAL MALIGNANCY IN KELANTAN

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DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR MASTER OF MEDICINE (RADIOLOGY)

UNIVERSITI SAINS MALAYSIA

2022

ACKNOWLEDGEMENT

I would like to express my utmost gratitude to Allah SWT for giving me the opportunity and endlessly guiding me throughout the completion of this thesis. The completion of this thesis would also not have been possible without the participation, cooperation, and assistance from so many people whose names may not all be enumerated. Their contributions are sincerely appreciated and gratefully acknowledged. However, I would like to place on record, my deepest and utmost appreciation, particularly to the following:

1. Dr. Khairil Amir Sayuti, my main supervisor, who had assisted and provided guidance in carrying out this study until its completion.
2. Dr. Muhammad Imran Kamarudin, as my co-supervisor, who was supportive and provided invaluable insights during the progress of this study.
3. Professor Dr. Mohd Shafie Abdullah, Associate Professor Dr. Mohd Ezane Aziz, Associate Professor Dr. Juhara Haron, Dr. Chandran Nadarajan, Dr. Ahmad Hadif Zaidin Samsudin, Dr. Wan Aireene Wan Ahmed, Dr. Nur Asma Sapiai, Dr. Nasibah Mohamad, Dr. Bazli Md Yusoff, Dr. Fattah Rahiman Ghazali, Dr. Ahmad Aizuddin Mohamad Jamali, Dr. Lau Chiew Chea (lecturers cum radiologists), all of whom had directly or indirectly contributed their ideas and comments to the success of this study.
4. Radiographers, colleagues, and all the other staff in the Department of Radiology, Hospital Universiti Sains Malaysia (HUSM).
5. Miss Mardhiah Kamaruddin, statistician who provided her expertise in the completion of this study.
6. Last but no least, my family for their unconditional love, support and motivation.

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LIST OF SYMBOLS, ABBREVIATIONS AND ACRONYMS

AKI	Acute Kidney Injury
CIN	Contrast-induced Nephropathy
CI-AKI	Contrast-induced Acute Kidney Injury
CG	Cockroft-Gault equation
CKD-EPI	Chronic Kidney Disease Epidemiology Collaboration Equation
CT	Computed Tomography
eGFR	Estimated Glomerular Filtration Rate
HPE	Histopathological Examination
IOCM	Iso-Osmolar Contrast Media
KDIGO	Kidney Disease Improving Global Outcomes
LIS	Laboratory Information System
LOCM	Low Osmolar Contrast Media
MDRD	Modification of Diet in Renal Disease
MPR	Multiplanar Reformation
MRI	Magnetic Resonance Imaging
PACS	Picture Archiving and Communication System
PUJO	Pelvi-ureteric junction obstruction
RIS	Radiology Information System
SPSS	Statistical Package for the Social Sciences
VR	Volume Rendering
WHO	World Health Organization

ABSTRAK

Latar belakang: Nefropati akibat kontras (CIN) merupakan satu komplikasi selepas imbasan *CT* berkontras, terutamanya bagi pesakit yang anggaran kadar penapisan glomerular (eGFR) rendah. Terdapat korelasi antara anggaran kadar penapisan glomerular dan nefropati akibat kontras dan juga korelasi antara isipadu buah pinggang dan anggaran kadar penapisan glomerular. Terdapat pelbagai cara kiraan isipadu buah pinggang, di mana imbasan *CT* berkontras diguna pakai secara meluas. Tujuan kajian ini dijalankan adalah untuk menentukan korelasi antara anggaran kadar penapisan glomerular, kiraan isipadu buah pinggang menggunakan imbasan *CT* dan nefropati akibat kontras dalam kalangan pesakit barah bukan buah pinggang yang menjalani imbasan *CT* buat kali pertama.

Metod: Kajian keratan lintang dijalankan di Hospital Universiti Sains Malaysia (HUSM), Kubang Kerian, Kelantan, Malaysia ke atas 59 pesakit barah bukan buah pinggang yang menjalani imbasan *CT* buat kali pertama. Kiraan isipadu buah pinggang dibuat menggunakan perisian *VitreaCore*. Fungsi buah pinggang digunakan untuk mengira anggaran kadar penapisan glomerular asas dan 24-48 jam selepas imbasan *CT* berkontras untuk menentukan nefropati akibat kontras. Insiden nefropati akibat kontras direkodkan dalam peratus. Korelasi antara kiraan isipadu buah pinggang menggunakan imbasan *CT* dan anggaran kadar penapisan glomerular menggunakan *Pearson Correlation Coefficient.* Purata isipadu buah pinggang menggunakan imbasan CT antara kumpulan nefropati akibat kontras atau tidak menggunakan *Independent t-test.*

Keputusan: Insiden nefropati akibat kontras adalah sebanyak 3.4%. Tiada korelasi yang signifikan di antara anggaran kadar penapisan glomerular dan kiraan isipadu buah pinggang menggunakan imbasan *CT* (P>0.05). Purata isipadu buah pinggang untuk kumpulan nefropati akibat kontras atau tidak adalah masing-masing 159.12 (19.28) *mls* dan 144.46 (27.30) *mls*, tiada beza purata yang signifikan direkodkan (P>0.05). Akan tetapi, terdapat korelasi signifikan antara anggaran kadar penapisan glomerular dan nefropati akibat kontras (P>0.05), kesemua pesakit adalah dari kumpulan 3b.

Kesimpulan: Kajian ini tidak menunjukkan korelasi yang signifikan antara anggaran kadar penapisan glomerular dan kiraan isipadu buah pinggang menggunakan imbasan *CT* berkemungkinan disebabkan oleh berat badan seseorang pesakit tidak diambil kira semasa melakukan anggaran kadar penapisan glomerular. Walau bagaimanapun, insiden nefropati akibat kontras adalah selaras dengan kajian-kajian terdahulu. Kajian yang lebih lanjut menggunakan kaedah lain untuk kiraan isipadu buah pinggang menggunakan imbasan *CT* dan anggaran kadar penapisan glomerular berkemungkinan akan menunjukkan hubungan korelasi antara anggaran kadar penapisan glomerular, kiraan isipadu buah pinggang menggunakan imbasan *CT* dan nefropati akibat kontras.

Kata kunci: CT Scan, Glomerular Filtration Rate, Acute Kidney Injury, Neoplasm, Renal Volume

ABSTRACT

Background: Contrast-induced nephropathy (CIN) is a known complication post-intravenous iodinated contrast study, particularly in patients with lower estimated Glomerular Filtration Rate (eGFR). Correlations between eGFR and CIN as well as between renal volume and eGFR have been established. Various methods were used for renal volume calculation. Of all, CT is the most feasible and widely used. The purpose of this study is to determine the correlation between eGFR, CT renal volumetry and CIN among non-renal malignancy patients going for initial contrasted-CT staging.

Methods: A cross-sectional study was conducted in Hospital Universiti Sains Malaysia (HUSM), Kubang Kerian, Kelantan, Malaysia on 59 patients who had been diagnosed with non-renal malignancy, and underwent initial contrasted-CT for staging. CT renal volumetry was obtained from 3D automated calculation from VitreaCore software. Renal function was used to calculate baseline eGFR and another renal function taken within 24-48 hours post-contrasted CT for evaluation of non-CIN or CIN patients. The CIN proportion was obtained in percentage. The correlation between CT renal volumetry and eGFR was tested using Pearson Correlation Coefficient. The mean CT renal volumetry between non-CIN and CIN patients was tested using Independent t-test.

Results: The proportion of CIN among non-renal malignancy patients was 3.4%. There was no correlation between baseline eGFR and CT renal volumetry ($P>0.05$). The mean (SD) CT renal volumetry for CIN and non-CIN patients were 159.12 (19.28) mls and

144.46 (27.30) mls, respectively; no significant mean difference of CT renal volumetry between CIN and non-CIN patients (P>0.05). However, there was significant correlation between the baseline eGFR and CIN (P<0.05) whereby all CIN patients are from stage 3b kidney disease.

Conclusion: Our study showed no correlation between baseline eGFR and CT renal volumetry probably because the patient's individual body weight was not accounted for in the eGFR calculation. Nonetheless, the proportion of CIN was consistent with previous studies. Further research using other methods for CT renal volumetry and eGFR calculation might be plausible to show the association between eGFR, CT renal volumetry and CIN.

Key words: CT Scan, Glomerular Filtration Rate, Acute Kidney Injury, Neoplasm, Renal Volume

CHAPTER 1: BACKGROUND

1.1 Introduction

Contrast-induced nephropathy (CIN) is a known complication developed in post-intravenous iodinated contrast study with an incidence of 0-24% (Mohammed *et al*., 2013). The risk of CIN is categorised into patient- and procedure-related. For patient-related, the risk includes renal impairment, diabetes mellitus, intravascular volume depletion, concomitant use of nephrotoxic medications, and malignancy patients. While for procedure-related, the risk includes administration of contrast media or repeated administration within 72 hours. This is due to intrarenal vasoconstriction or direct tubular toxicity, which particularly affects patients by reducing kidney reserved function. Therefore, proper management with preventive measures must be carried out prior to and after the contrast study. Hospital Universiti Sains Malaysia (HUSM) practises hydration, N-acetylcysteine administration in selected cases and serum creatinine monitoring pre- and post-contrast study in patients with lower estimated Glomerular Filtration Rate (eGFR). Other preventive measures that are offered include the usage of medication (sodium bicarbonate) or prophylactic haemodialysis or haemofiltration in selected cases. However, according to previous studies, the latter preventive measure does not prevent CIN.

In many studies, there is a correlation seen between eGFR and CIN. There is also correlation seen between renal volumetry and eGFR, proven in some of the previous studies. Lower eGFR is associated with lower renal mass and thus increases the risk for CIN.

There are various methods used for renal volumetry calculation, either by ultrasound, computed tomography (CT), magnetic resonance imaging (MRI) or nuclear

renography (Breau *et al.*, 2013). Of all those, CT is the most feasible and widely used, either by using ellipsoid formula or 3D software.

For patients with malignancy, a confirmed case with histopathological examination (HPE) will need a contrasted-CT study for staging and disease evaluation to determine further management. According to Li *et al.* (2019), the incidence of acute kidney injury (AKI) in malignancy is common, this accounts for about 12.4% and is due to various causes. The incidence of CIN in malignant patients is about 2.5% (Jeon *et al.*, 2019). Contrasted-CT using iodinated contrast media will result in either normal or CIN if severe, post-contrast study, particularly in patients with lower eGFR. In HUSM, we use low-osmolar contrast media (LOCM) for most cases and iso-osmolar contrast media (IOCM) for selected cases.

1.2 Objectives

1.2.1 General Objective

To study the CIN, eGFR and CT renal volumetry among non-renal malignancy patients in HUSM.

1.2.2 Specific Objectives

1. To describe the CIN proportion among non-renal malignancy patients.
2. To determine the correlation between baseline eGFR and CT renal volumetry among non-renal malignancy patients.
3. To compare mean of CT renal volumetry between non-CIN and CIN groups, post-contrast CT among non-renal malignancy patients.

1.3 Hypothesis

There is a correlation between CT renal volumetry and eGFR as well as mean difference of CT renal volumetry between non-CIN and CIN groups among non-renal malignany patients.

1.4 Research Question

1. Is there any correlation between CT renal volumetry and eGFR?
2. Is there any mean difference of CT renal volumetry among the non-CIN and CIN groups?

CHAPTER 2: LITERATURE REVIEW

2.1 Contrast-induced Nephropathy

Contrast-induced acute kidney injury (CI-AKI) is a common iatrogenic complication in post-intravenous iodinated contrast study. If severe, it can develop into a reversible temporary complication known as contrast-induced nephropathy (CIN). Kidney Disease Improving Global Outcomes guidelines (KDIGO) define CI-AKI as an increase in serum creatinine more than 0.3 mg/dL (26.5 mmol/L) within 48 hours or increase in serum creatinine to more than 1.5 times baseline, which is known or presumed to have occurred within or prior to 7 days period or urine volume less than 0.5 ml/kg/h for 6 hours following administration of intravascular contrast media (Official Journal of The International Society of Nephrology, 2013). The incidence of CIN is about 0-24% (Mohammed *et al*., 2013). There is associated 6% incidence of in-hospital mortality rate associated with CIN (Chang and Lin, 2013).

The proposed pathophysiology of CIN includes intrarenal vasoconstriction resulting in medullary hypoxia releasing reactive oxygen species with direct renal tubular toxicity (Persson *et al.*, 2005; Hossain *et al.*, 2018). When there is reduction in a renal parenchymal mass, there will be reduction in blood flow that will increase the risk of ischemia in patients with lower eGFR (Persson *et al.*, 2005). The risk for CIN can be divided into two, patient and procedure-related (Stacul *et al.*, 2011). Patient-related factor includes ageing, pre-existing renal impairment, diabetes mellitus, intravascular volume depletion, and concomitant use of nephrotoxic medications. Procedure-related factor includes the contrast media osmolarity and volume as well as repeated administration of

contrast media within 72 hours (Hossain *et al.*, 2018). The use of low osmolar contrast media (LOCM) can lower the incidence of CI-AKI (Rudnick *et al*., 2020). There might be no changes of renal function (non-CIN) or CIN for outcome of post-contrast study depending on the level of serum creatinine post-contrast study.

Few preventive methods had been adapted to prevent CIN, namely hydration, administration of sodium bicarbonate or N-acetylcysteine, and prophylactic hemodialysis or hemofiltration. Hydration has been proven as the most effective method in reducing risk of CIN (Persson *et al.*, 2005). As CIN is a preventable condition, the necessary preventive measures have to be adapted accordingly to prevent its occurrence.

2.2 Estimated Glomerular Filtration Rate (eGFR)

The best assessment of kidney function is made by calculation of glomerular filtration rate (eGFR) (Stevens *et al.*, 2006). There are two methods to calculate eGFR, which are measuring of eGFR by using exogenous filtration marker and equation-estimated eGFR through the use of endogenous filtration marker (Stevens *et al.*, 2006). eGFR is more widely used and calculations can be made using Cockroft-Gault (CG) equation, Modification of Diet in Renal Disease (MDRD) equation or Chronic Kidney Disease Epidemiology Collaboration equation (CKD-EPI), in which the latter is the most accurate and widely used nationwide (Michels *et al.*, 2010; Levey *et al.*, 2009). Plasma creatinine will be taken and eGFR will be calculated using the CKD-EPI equation (Ministry of Health Malaysia, 2018). The equation variables include age, race and sex, because of the difference in muscle mass. eGFR is important in staging the kidney disease (Michels *et al.*, 2010; Ministry of Health Malaysia, 2018). There is increased risk for CIN

in patients with lower eGFR (Ellis *et al.*, 2019). Malaysia Clinical Practice Guideline on Management of Chronic Kidney Disease has categorised chronic kidney disease following the eGFR as follows; stage 1 has eGFR of more than 90, stage 2 has eGFR in between 60-89, stage 3a has eGFR in between 45-59, stage 3b has eGFR in between 30-44, stage 4 has eGFR in between 15-29, and stage 5 has eGFR less than 15 (Ministry of Health Malaysia, 2018).

2.3 Renal Volumetry

Renal volumetry is used to gauge the functional reserve of kidneys (Gupta *et al.*, 2012). There are few methods for renal volumetry measurement, either by ultrasound, computed tomography (CT), magnetic resonance imaging (MRI), or nuclear renography (Breau *et al.*, 2013). The most accurate method for renal volumetry measurement is nuclear renography, however, CT is more widely available and correlates well with renal renography (Morrisroe *et al.*, 2010). Ultrasound is operator-dependent while MRI is susceptible to signal intensity and artefact as well as time-consuming (Liu *et al.*, 2016).

CT renal volumetry can be measured either by ellipsoid formula or 3D software calculation in which both methods are correlated (Breau *et al.*, 2013). The ellipsoid method is more practical and widely available than the 3D software method. However, a study had shown that CT renal volumetry calculated using ellipsoid method slightly underestimates the renal volume from a 3D software method (Jeon *et al.*, 2019). Ultrasound and MRI renal volumetry using ellipsoid formula also underestimate the renal volume (Breau *et al.*, 2013). There is direct relationship seen between CT renal volumetry and kidney function or eGFR, mentioned in many studies. The kidney function per unit

volume is constant for each individual (Matsuo *et al.*, 2019). Pubmed and Google Scholar search was carried out using the keywords “renal volume and CIN” and “renal volume with CIN”. To date, we have found no study which focuses on the correlation between the CT renal volume and CIN.

2.4 Pre-chemotherapy, Non-renal Malignancy Patients

Malignancy is a devastating disease, in which some occur with multiorgan involvement. The normal physiological functional reserve of the organ might change. The incidence of acute kidney injury (AKI) in malignancy is common and accounts for about 12.4% (Li *et al.*, 2019). Types of malignancy include renal cancer (27.3%), multiple myeloma (24.1%), and leukaemia (23.9%) (Li *et al.*, 2019). Contributing factors include ageing, pre-existing comorbidities, electrolyte imbalance, and sepsis. Most malignancy-related AKI is due to malignant infiltration, tumour lysis syndrome, radiocontrast agent or nephrotoxic drugs (Li *et al.*, 2019). The incidence of CIN in malignant patients is about 2.5% (Jeon *et al.*, 2019).

CT contrast study is a frequent method used for staging, evaluating and monitoring disease progression in malignancy (Hong *et al.*, 2016). Patient’s condition prior to contrast study plays an important role in contributing to CIN post-contrast study. It is suggested that consecutive studies between 24 to 72 hours, hypotension, dehydration, liver cirrhosis, blood urea nitrogen to creatinine ratio of more than 20 and peritoneal carcinomatosis, are associated with higher risk of CIN (Hong *et al.*, 2016).

2.5 Conceptual Framework

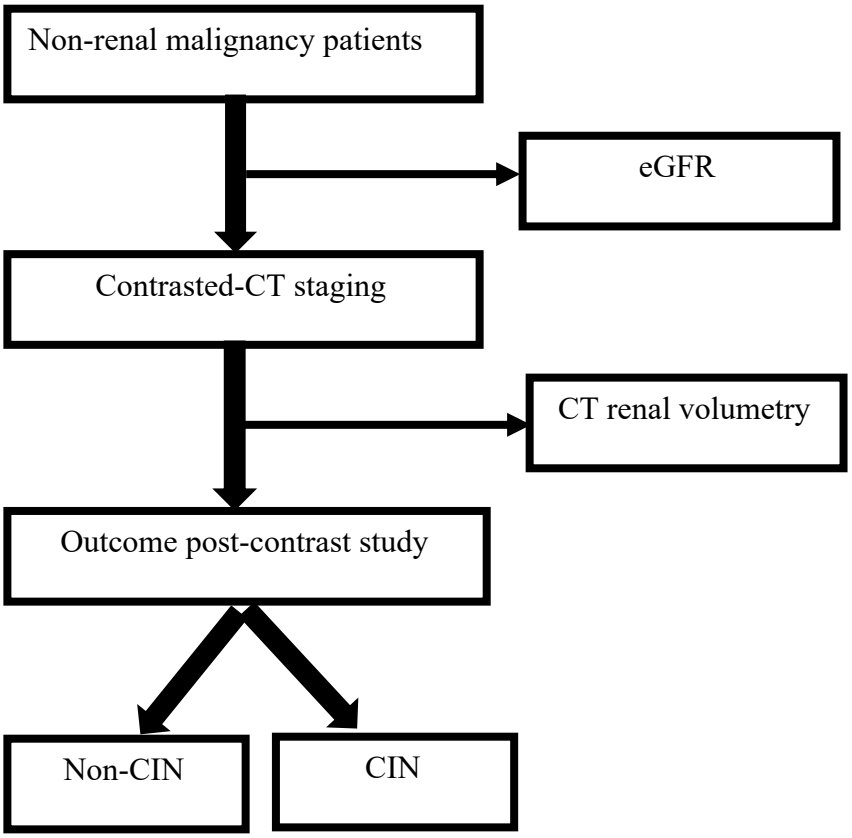

Figure 1: Conceptual framework

2.6 Rationale of Study

This study is conducted to determine the correlation between the eGFR, CT renal volumetry and CIN. CT is chosen to measure the renal volume because of its feasibility. There is a correlation seen between eGFR with CT renal volumetry and eGFR with CIN. However, to date, there has been no study on the relationship between renal volume and CIN. Therefore, this study is conducted to compare the mean renal volume of patients between CIN and non-CIN groups. It is aimed to demonstrate whether the CT renal volume can be used as an adjunct in predicting the risk of CIN, in addition to eGFR. This will help to estimate the risk of CIN and the requirement for renal function monitoring post-intravenous iodinated contrast study.

As malignancy affects the normal physiological functional reserve of the organs, malignancy patients are chosen as subjects, in particular non-renal malignancy as we need to measure the renal volume. Pre-chemotherapy group is chosen to avoid bias of long-term complication of chemotherapy-induced nephrotoxicity (Li *et al.*, 2019). This study is conducted to ascertain whether patients with normal renal functions or renal volume are also at risk to develop CIN post-contrast study. As for our current practice, patients with lower eGFR will be admitted for renal protection protocol and function monitoring post-contrast study. If the result of this study proves that patients with normal renal function or renal volume also develop CIN, we may propose that all malignant patients have renal function monitored post intravenous contrast study.

CHAPTER 3: METHODOLOGY

3.1 Study Design

This is a cross-sectional study which was conducted in HUSM, Kubang Kerian, Kelantan, Malaysia for a period of one and a half years from May 2020 to November 2021. Data were collected from January 2015 to November 2021.

3.2 Sample Population

i. Reference population – Patients with confirmed case of non-renal malignancy in Kelantan.

ii. Source population – Patients with confirmed case of non-renal malignancy who underwent contrasted-CT staging in HUSM from 2015 onwards.

iii. Sampling frame – Patients with confirmed case of non-renal malignancy who underwent contrasted-CT staging in HUSM from 2015 onwards based on inclusion and exclusion criteria.

3.3 Sample Size Calculation

1. For objective 1, the sample size is calculated using single proportion formula to estimate the proportion of CIN in non-renal malignancy patients based on incidence of CIN in malignancy patients which accounts for 2.5% in a study done by Jeon *et al.* (2019). A sample size of 47 patients is estimated to be sufficient, including the anticipated dropout rate of 20% (95% confidence, $Z\alpha = 1.96$ and precision, $d = 0.05$).

   Single proportion formula:

   $n= (Z(1-\alpha/2)/\Delta)^2*P(1-P)$

   $38= (1.96/0.05)2*0.025(1-0.025)$

2. For objective 2, the sample size is calculated using Sample Size Calculator for Correlation Analysis by NMY. Using correlation coefficient (r) between CT renal volumetry and eGFR of 0.4 based on a study by Adibi *et al.* (2016) with 5% of type 1 error (α), 20% of type II error (β), the calculated sample size (n) is 47. By adding anticipated dropout rate of 20%, the corrected sample size (n_c) is 59.

3. For objective 3, as there is no previous study done, the maximum corrected sample size is based on previous two objectives. Therefore, the maximum corrected sample size is 59.

3.4 Sampling Method

No sampling method was applied. A total of 455 non-renal malignancy patients underwent contrasted-CT staging from January 2015 to 2021. Only 59 patients that fulfilled the inclusion and exclusion criteria were enrolled in the study.

3.5 Inclusion Criteria

1. All subjects aged 18 years old and above with confirmed case of non-renal malignancy (both solid and liquid tumour).
2. Availability of CT images in Picture Archiving and Communication System (PACS).
3. Availability of serum creatinine pre (within 3 months) and post-contrast study (within 48 hours post-contrast study).
4. First CT staging as pre-chemotherapy work-up.

3.6 Exclusion Criteria

1. Subjects with ambiguous status of malignancy.
2. Suboptimal CT images in PACS system.
3. Prior history of chemotherapy.
4. Patients with congenital renal anomalies, renal parenchymal abnormalities, obstructive renal disease and a single kidney.

3.7 Research Tools and Variables

1. Radiology Information System (RIS) – Picture Archiving and Communication System (PACS) version 6.0 and ViaRad for image acquisition and demographic/ clinical data information.
2. Histopathology results from Lab Information System (LIS) Pathology application version 2.0 database.
3. Serum creatinine in mmol/L obtained from LIS RESULT® application version 6.6 for eGFR calculation and outcome post-contrast study. eGFR, mL/min/1.73m² will be calculated using the CKD-EPI equation by Calculate by QxMD software from the web https://qxmd.com/calculate/calculator_251/egfr-using-ckd-epi (QxMD, 2019).

   Other parameters that need to be entered are gender, race and age.

   Serum creatinine post-contrast study is obtained within 48 hours post-contrast study to determine the outcome post-contrast study (non-CIN or CIN groups) is manually calculated.
4. Image acquisition obtained from Toshiba Aquilion Prime CT scanner (160 slices, 80 detectors) and Siemens SOMATOM Definition AS+ CT scanner (128 slices, 64 detectors), sent to VitreaCore software.
5. VitreaCore software version 6.7.2021.1 was used for 3D volumetry calculation, obtained in mls.
6. Statistical Product and Service Solutions (SPSS) for Windows, SPSS Inc.© (Version 26, SPSS Inc., Chicago, IL, USA) used for data analysis.

3.8 Operational Definition

1. Non-renal malignancy is defined as all cases of malignancy including both solid and liquid tumours with proven HPE excluding all types of renal malignancy.
2. Patients with renal anomalies are defined as congenital renal anomalies and classified according to the abnormal embryological development into abnormalities in the renal parenchymal development, aberrant embryogenic migration and abnormalities of the collecting system (Ramanathan *et al*., 2016). Renal parenchymal abnormalities include multi cystic dysplastic kidney (MCDK), renal hypoplasia, number (agenesis or supernumerary), shape and cystic renal diseases. Aberrant embryogenic migration encompasses abnormal location and fusion anomalies. Collecting system abnormalities include duplex kidneys and pelvi-uretero junction obstruction (PUJO). Patients with renal abnormalities include obstructive renal disease (hydronephrosis) or difference in size in both renal of more than 2 cm.
3. Outcome of post-contrast study (Official Journal of The International Society of Nephrology, 2013; Li *et al*., 2019).

   Non-CIN – No or increment of serum creatinine of less than 0.3 mg/dL (26.5 mmol/L) within 48 hours following administration of intravascular contrast media.

   CIN – An increment of serum creatinine of more than 0.3 mg/dL (26.5 mmol/L) within 48 hours following administration of intravascular contrast media.

3.9 Data Collection

Patient Cohort

This is a cross-sectional study that was conducted in HUSM, Kubang Kerian, Kelantan, Malaysia from May 2020 to November 2021. Data collected were from January 2015 to November 2021. This study had obtained approval from the Human Research Ethics Committee of USM (USM/JEPeM/19120887). A total of 455 were diagnosed with non-renal malignancy (HPE proven) did the initial contrasted-CT staging with availability of serum creatinine and CT images in Picture Archiving and Communication System (PACS) were chosen. However, 396 patients were excluded due to ambiguous status of malignancy, prior history of chemotherapy, congenital renal anomalies, renal parenchymal abnormalities, obstructive renal disease, a single kidney or suboptimal images in PACS system. Hence, a total of 59 patients were enrolled in this study. The patients were identified through Radiology Information System (RIS).

CT Renal Volumetry

CT images for selected cases were retrieved from PACS and sent to VitreaCore software version 6.7.2024.1 for 3D volumetry calculation. Using VitreaCore software, multiplanar reformation (MPR) images and volume rendering (VR) images were used to calculate the renal volume for both kidneys. Subsequently, the automated volume was generated from the software. The steps were shown below. The volume obtained was recorded in the data collection sheet.

Image analysis:

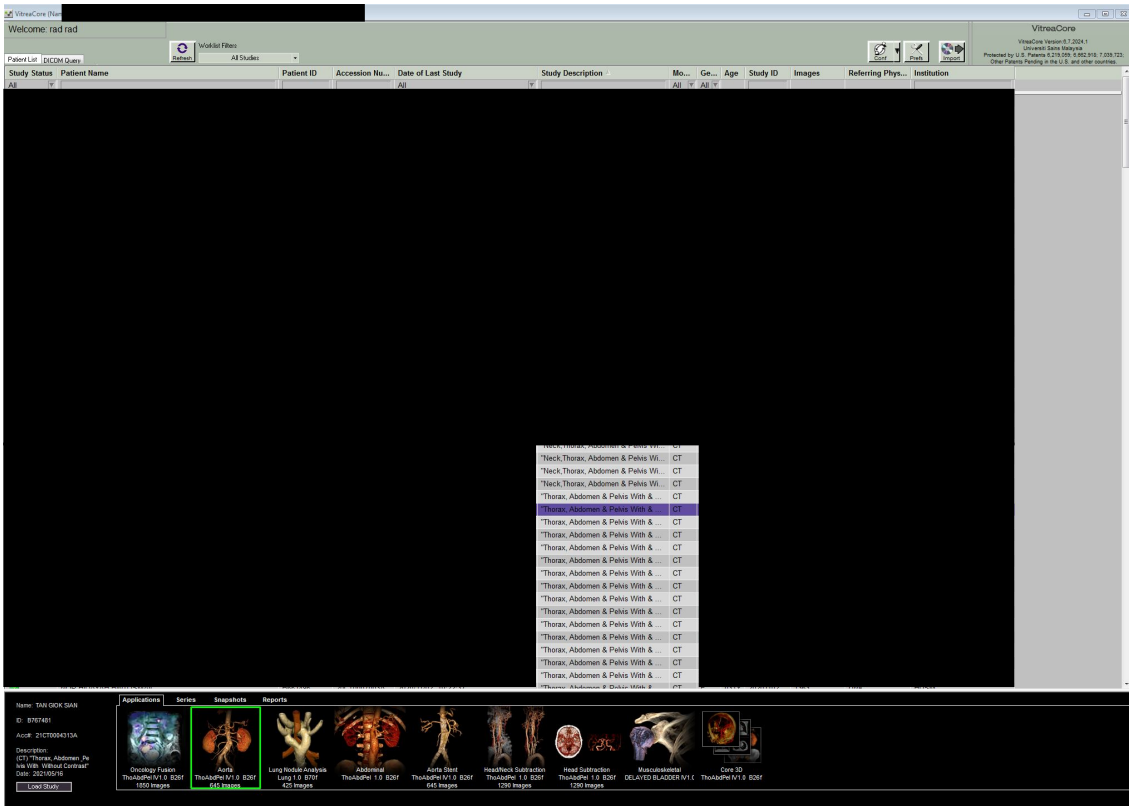

Figure 2: Selection of application Aorta in VitreaCore software.

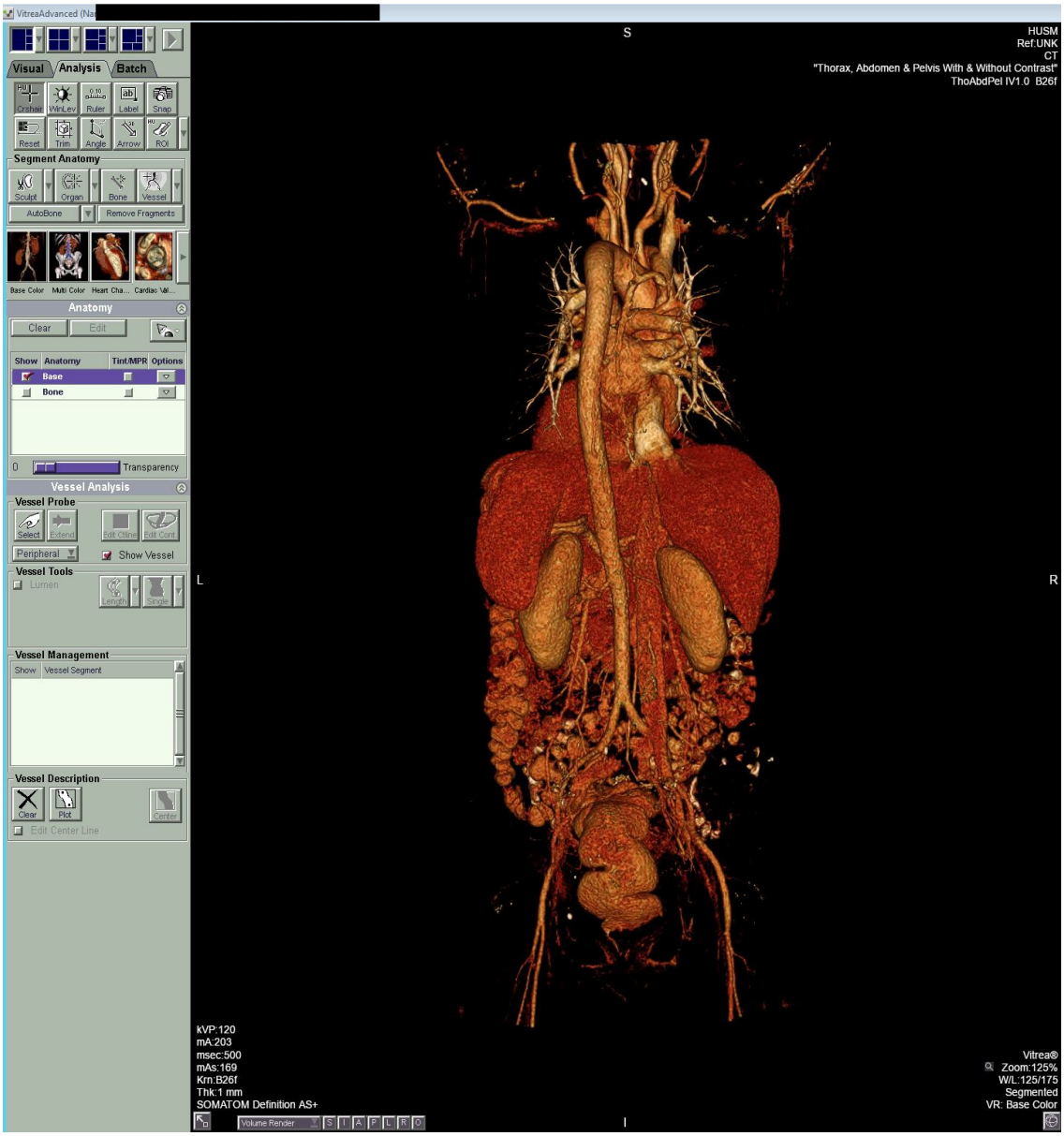

Figure 3: Volume rendered (VR) image of contrast CT thorax, abdomen, and pelvis.

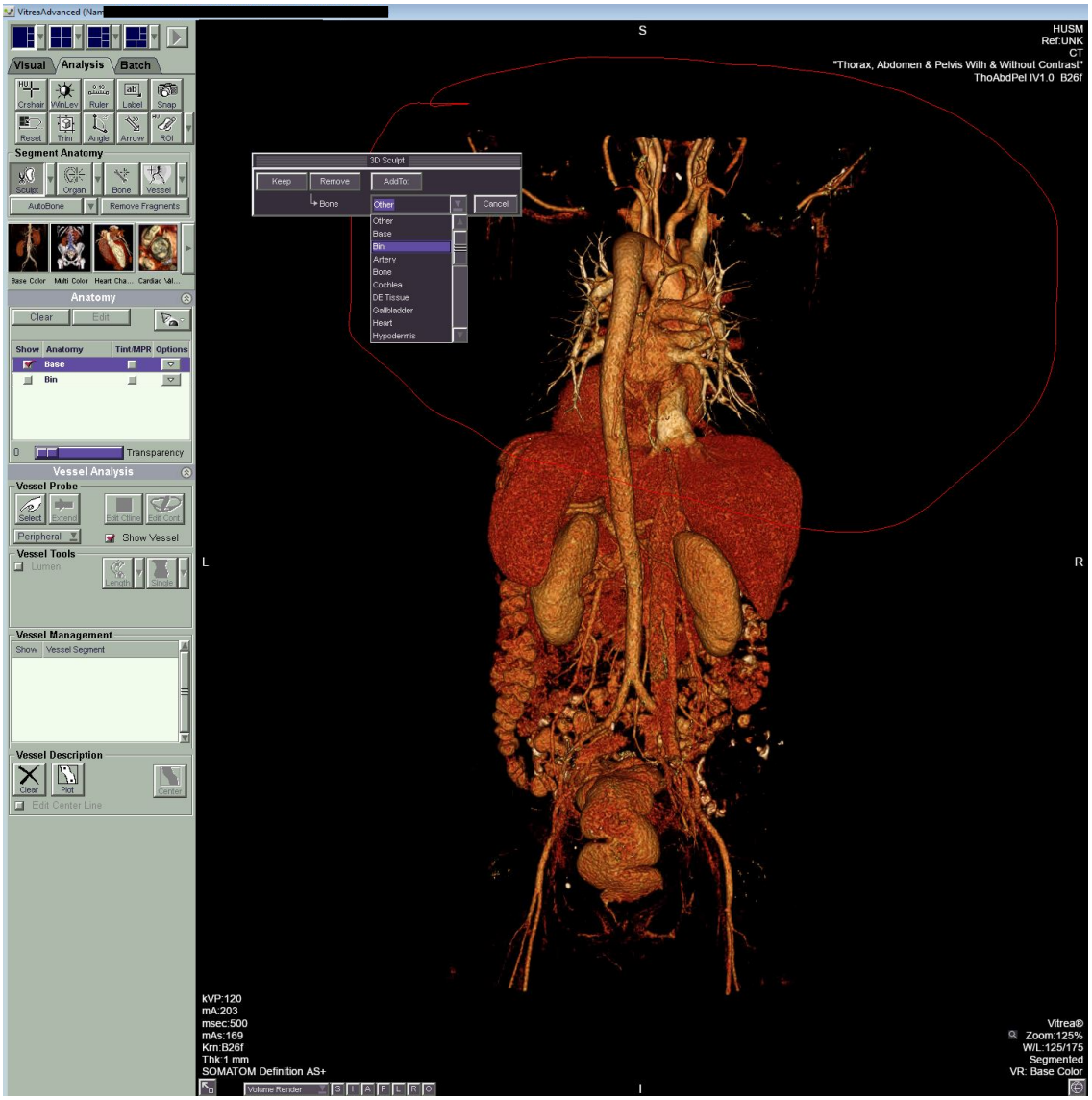

Figure 4: VR image cropping.

Images were cropped using the sculpt function, leaving only both kidneys.

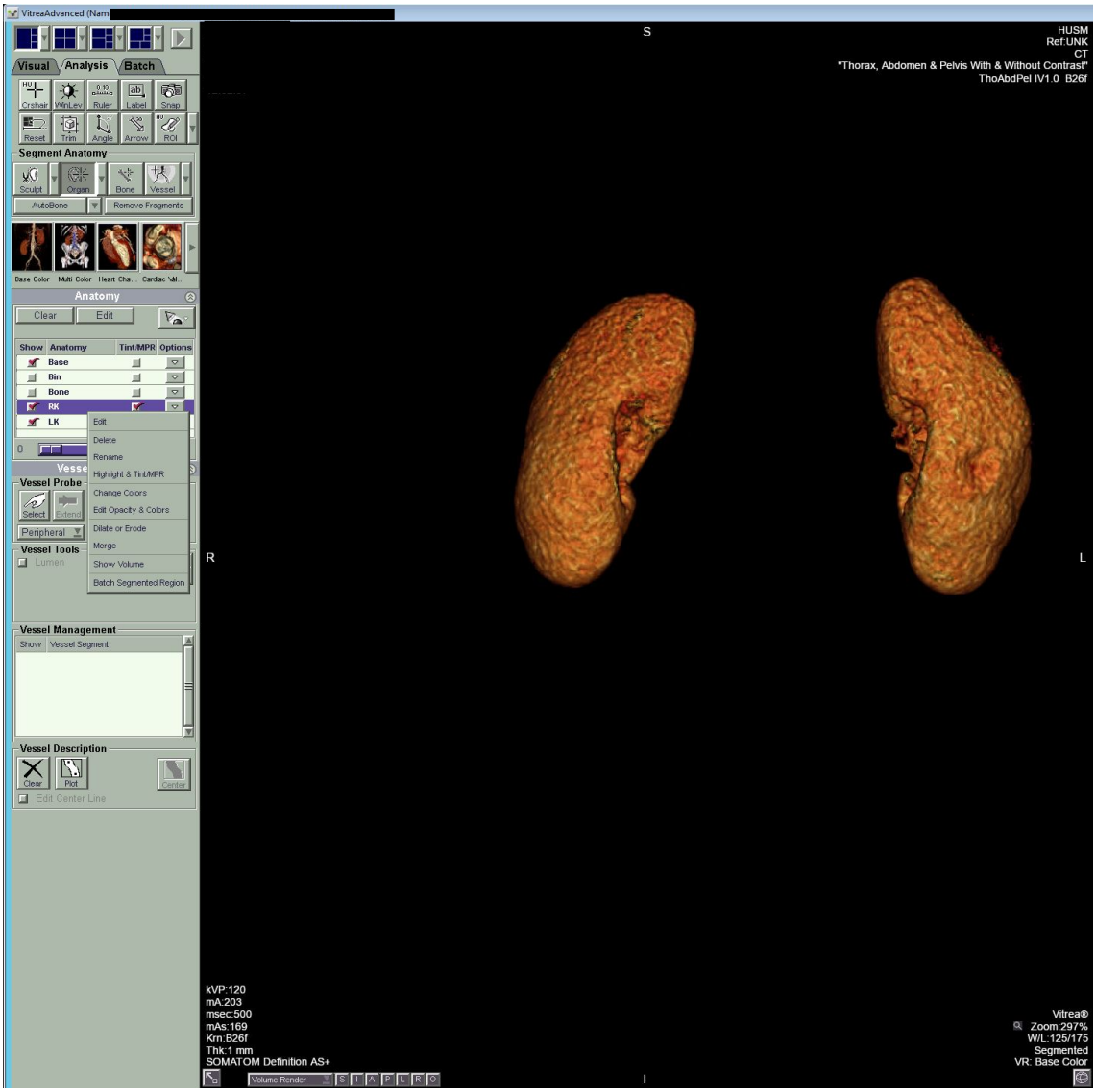

Figure 5: Final result post VR image cropping.

Both kidneys are labelled, RK for right kidney and LK for left kidney.

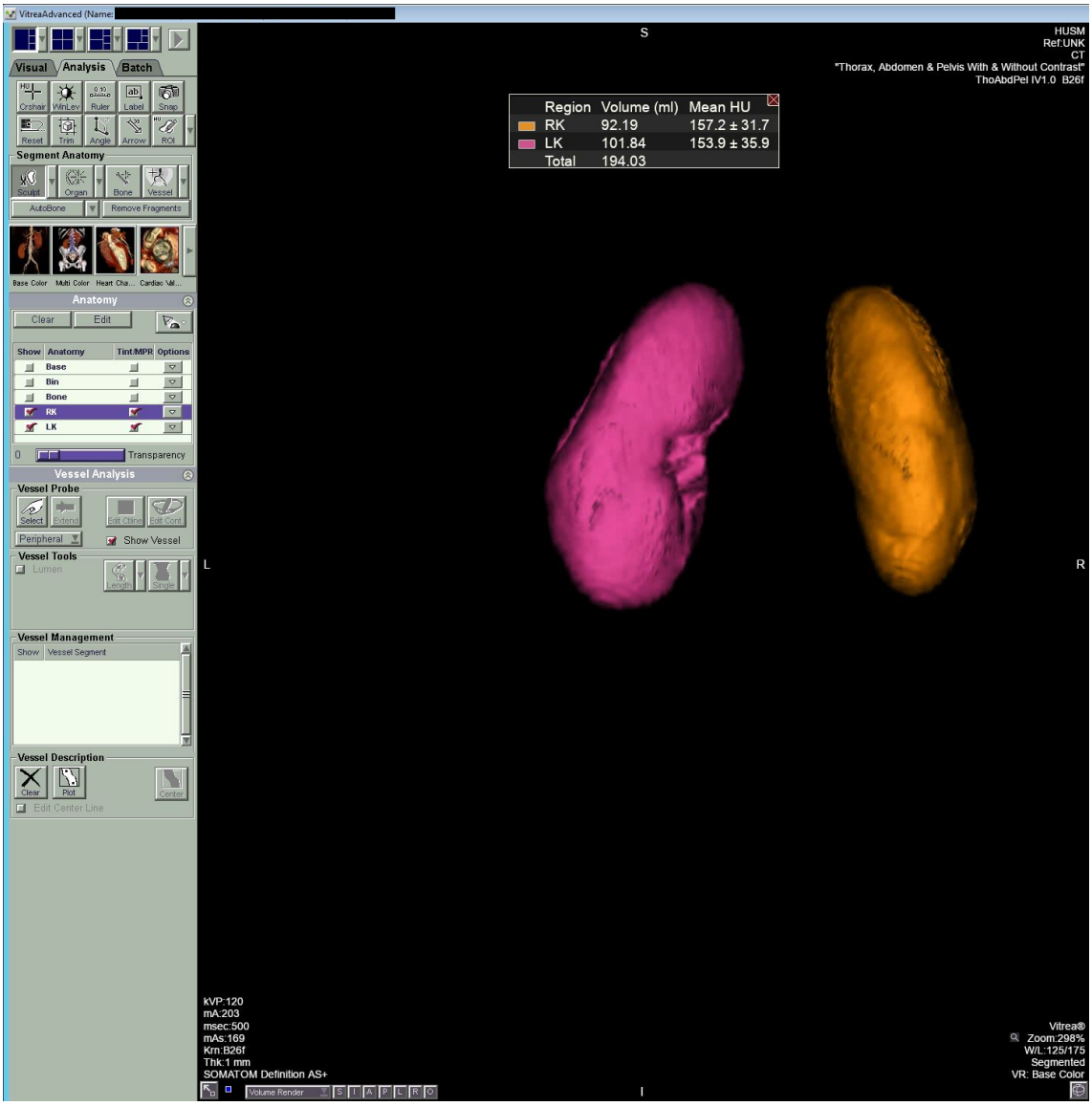

Figure 6: Automated renal volume calculation.

Option ‘show volume’ was selected to calculate the volume for each kidney.

eGFR

The renal function test was obtained from the LIS RESULT® application, both pre- and post-contrasted CT. Renal function taken within 3 months prior to contrasted-CT for baseline and within 24-48 hours post-contrasted CT for outcome post-contrast study (non-CIN or CIN groups). Baseline renal function was used to calculate the eGFR using the CKD-EPI equation calculated using the QxMD software (QxMD, 2019). Contrast-induced nephropathy is defined as an increment of serum creatinine of more than 0.3 mg/dL (26.5 mmol/L) within 48 hours post-contrasted study. All the data were recorded in the data collection sheet.

Histopathology results

The histopathological reports of the tumour were obtained from the Lab Information System (LIS) database. Only patients with availability of HPE were included in this study.

Data collection

Data taken included age, sex, race, and comorbid. These data were taken from the Radiology Information System (RIS) and patients' medical records.

Validation

The renal volumetry was autogenerated from the VitreaCore software. Since this software was user-friendly and the measuring technique was straightforward, no validation was required.

3.10 Statistical Analysis

All data were analysed using Statistical Product and Service Solutions (SPSS) for Windows, SPSS Inc.© (Version 26, SPSS Inc., Chicago, IL, USA). The descriptive statistics were used for discrete variables (age, sex, race, and co-morbid) and CIN proportion was presented as n=frequency (%). Pearson Correlation Coefficient was used to determine the correlation between the CT renal volumetry and eGFR. Independent t-test was used to compare the mean CT renal volumetry between normal and CIN patients. The level of significance was set at $P<0.05$. Statistical analyses were presented in tables.

3.11 Confidentiality and Privacy

The subjects were identified using a unique serial number. No identifiable data was shared publicly. Upon completion of the study, all data were stored in CDs, and the database on the computer was erased. The data were retained by the researchers for knowledge purposes only. Neither the name nor any identifying information was used in any publication or presentation resulting from this study.

3.12 Ethical Consideration

The study was approved by Human Research Ethics Committee of Universiti Sains Malaysia (USM/JEPeM/19120887).

3.13 Study Flow Chart

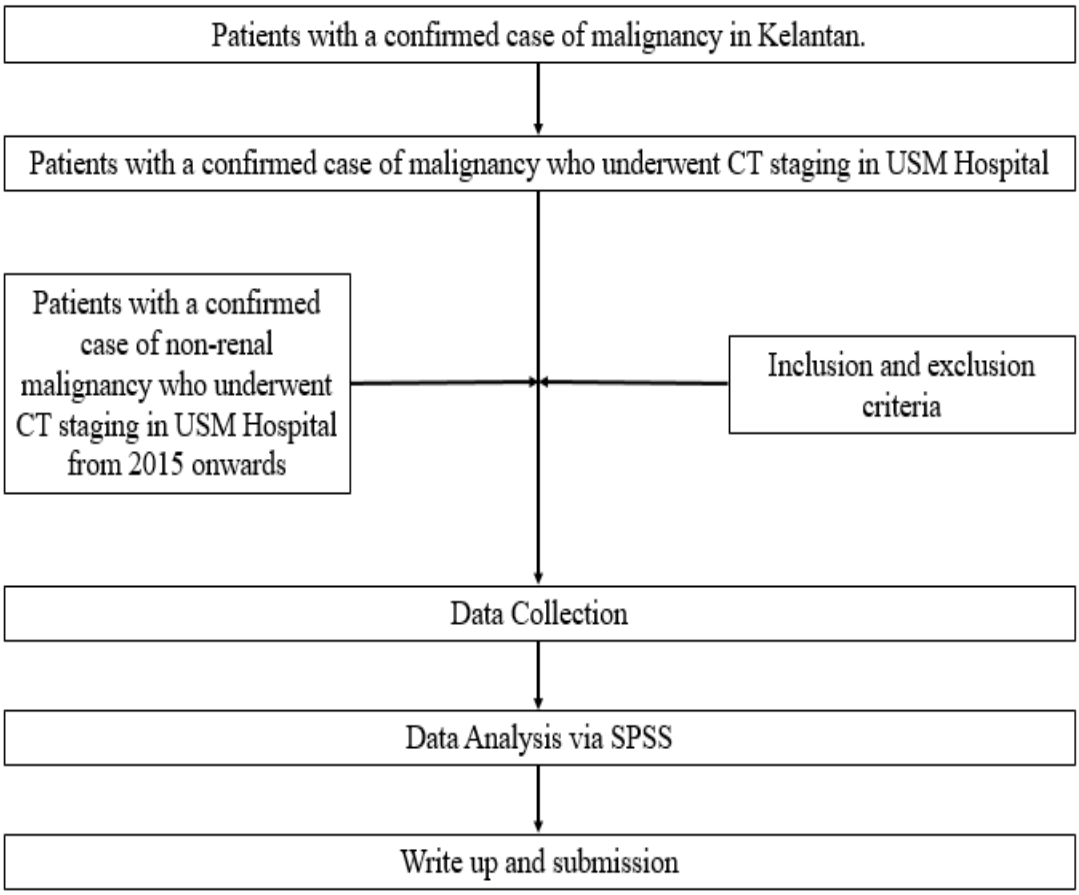

Figure 7: Study Flow Chart