



UNIVERSITI PUTRA MALAYSIA

**EVALUATION OF OPTIMUM SCAN DELAY FOR POST-CONTRAST
CONE BEAM COMPUTED TOMOGRAPHY (CBCT) OF THE CANINE
ABDOMEN**

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**EVALUATION OF OPTIMUM SCAN DELAY FOR POST-CONTRAST CONE
BEAM COMPUTED TOMOGRAPHY (CBCT) OF THE CANINE ABDOMEN**

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A project paper submitted to the Faculty of Veterinary Medicine, Universiti Putra
Malaysia In partial fulfillment of the requirement for the DEGREE OF DOCTOR OF
VETERINARY MEDICINE, Universiti Putra Malaysia, Serdang, Selangor Darul Ehsan.

MARCH 2017

CERTIFICATION

It is hereby certified that we have read this project paper entitled “Evaluation of Optimum Scan Delay for Post-contrast Cone Beam Computed Tomography (CBCT) of the Canine Abdomen”, by Lau Li Jiing and in our opinion, it is satisfactory in terms of scope, quality, and presentation as partial fulfillment of the requirement for the course VPD 4999 – Project.

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DEDICATIONS

To God Almighty,
For the strength and spiritual support to complete the project

My Beloved Father & Mother,
Sisters,
For encouraging and supporting me all the way to success

And my respected lecturers,
For the mentorship and unrelenting support throughout this project

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LIST OF ABBREVIATIONS

CBCT	Cone Beam Computed Tomography
CE-CBCT	Contrast-enhanced Cone Beam Computed Tomography
CT	Computed Tomography
HU	Hounsfield unit
MSCT	Multi-slice Computed Tomography
ROI	Region of interest

ABSTRAK

Abstrak daripada kertas projek yang dikemukakan kepada Fakulti Perubatan Veterinar untuk memenuhi sebahagian daripada keperluan kursus VPD 4999-Projek Ilmiah Tahun Akhir.

PENILAIAN WAKTU KELENGAHAN IMBASAN OPTIMUM UNTUK PASCA KONTRAS MENGGUNAKAN TOMOGRAFI KOMPUTER ALUR KON DI BAHAGIAN ABDOMEN ANJING

Oleh

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2017

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Tomografi komputer alur kon (CBCT) adalah teknologi pengimejan canggih yang digunakan untuk pelbagai aplikasi klinikal termasuk penyelidikan dan diagnostik. Penggunaan CBCT sebagai alat diagnostik dalam perubatan veterinar terutamanya bagi tisu lembut kurang digunakan kerana maklumat yang terhad di dalam protokol pengimbasan. Oleh itu, tujuan projek ini dibuat adalah untuk menentukan waktu kelengahan imbasan optimum untuk pasca kontras menggunakan CBCT bagi saluran

darah utama dan pelbagai organ dalaman di abdomen anjing. Pengimejan pra-kontras telah dilakukan ke atas tiga anjing dan penimejan pasca-kontras dilakukan pada kelengahan imbasan yang berbeza iaitu pada 0 saat, 30 saat dan 1 minit 30 saat. Intensiti radiasi pada saluran darah; aorta, caudal vena dan vena portal dan juga organ-organ dalam abdomen; hati, limpa dan pelvis akan diukur dalam unit Hounsfield (HU). Semua saluran darah utama dan organ-organ abdomen jelas digambarkan pada imbasan 30 saat. Walau bagaimanapun, tiada peningkatan kontras dilihat dalam saluran darah pada 0 saat walaupun organ-organ abdomen lain telah dipertingkatkan sebaliknya. Pengimejan pada 30 saat kelengahan imbasan menghasilkan peningkatan kontras yang sama pada 1 minit 30 saat kelengahan imbasan tetapi kami tidak mencadangkan protokol ini kerana isu-isu keselamatan yang berkaitan dengan penyuntikan agen kontras. Kesimpulannya, CBCT boleh dioptimumkan untuk penilaian saluran darah utama dan organ-organ abdomen pada anjing bagaimanapun kajian menggunakan bilangan besar anjing adalah diperlukan pada masa akan datang. Penubuhan protokol pengimbasan pasca kontras pasti akan meningkatkan nilai diagnostik kepada pesakit haiwan kecil.

Kata Kunci: CBCT, anjing, abdomen, kelengahan imbasan optimum, Hounsfield unit

ABSTRACT

An abstract of the project paper presented to the Faculty of Veterinary Medicine in partial fulfillment of the course VPD 4999-Final Year Project.

EVALUATION OF OPTIMUM SCAN DELAY FOR POST CONTRAST CONE BEAM COMPUTED TOMOGRAPHY (CBCT) OF THE CANINE

ABDOMEN

by

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2017

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Cone beam computed tomography (CBCT) is an advanced imaging technology used for various clinical applications including research and diagnostic. The application of CBCT as a veterinary diagnostic tool particularly for soft tissue is under-utilized due to limited information available on the scanning protocol. Therefore the aim of this study is to determine the optimum scan delay for post-contrast study using CBCT for major blood vessels and various organs in the canine abdomen. Pre-contrast study was performed on three dogs and post-contrast images were obtained at different scan delay;

0 second, 30 seconds, 1 minute 30 seconds. Attenuation for blood vessels; aorta, caudal vena cava and portal vein and also abdominal organs; liver, spleen, and renal pelvis were measured in Hounsfield unit (HU). All blood vessels and abdominal organs were clearly visualized at 30 second delay. There was no contrast enhancement seen in blood vessels at 0 second although other abdominal organs were enhanced by contrast. The 30 seconds scan delay produced the similar contrast enhancement at 1 minute 30 seconds scan delay however we do not recommend this protocol due to safety issues related to contrast administration. In conclusion, CBCT can be optimized for evaluation of blood vessels and abdominal organs in dogs however a study with larger number of animals are warranted in the future. Establishment of post-contrast scanning protocol certainly would provide diagnostic values to small animal patients.

Keywords: CBCT, canine, abdomen, optimum scan delay, Hounsfield unit

1.0 INTRODUCTION

Computed tomography (CT) has been recognized as an important diagnostic tool since mid of 1970s. The technology has significantly improved in the last few decades that features short scanning time and high quality images allowing the technique to become more robust. There are multiple types of CT available in the market, including cone beam computed tomography (CBCT) and multi-slice computed tomography (MSCT). The most commonly used machine is MSCT as it provides high soft tissue resolution and shorter scanning time however the technology is not readily affordable by small veterinary practices. CBCT has been a good alternative and its application has become increasingly popular as it is more economical and compact compared to MSCT. CBCT consists of an X-ray tube and a flat panel detector mounted on a C-arm gantry. A cone-shaped source of ionizing radiation is directed through the middle of the area of interest onto an area x-ray detector on the opposite side (Scarfe & Farman, 2008). The scanning system is also able to acquire and reconstruct three-dimensional (3D) images that can be analyzed and visualized by specialized computer software. The Hounsfield unit (HU) is an attenuation coefficient measurement commonly used in computed tomography scanning to express CT numbers in a standardized and convenient form based on the arbitrary definitions of air and water. The radiodensity of distilled water at standard temperature and pressure is equal to 0 HU whereas the air is equal to -1000 HU.

CBCT application in veterinary medicine is currently limited to research and dentistry hence explains the limited number of literatures on the optimum scanning protocols for soft tissues. A good soft tissue study would require administration of iodine contrast. Adequate contrast would assist in providing high resolution images and able to demonstrate clear soft tissue discrimination and potential lesions. However, the use of CBCT for soft tissue study is currently under-utilized. Due to the increasing number of cases for soft tissue studies seen in our hospital, there is a need to evaluate the optimum scan delay for various soft tissues. This research will be conducted on a small scale study. This is mainly to evaluate optimum scan delay and sample size in an attempt to predict the appropriate sample size and establish an optimum scan delay protocol of canine abdomen in the future as a full scale study. The contrast agent iohexol will be used in this study as it is non-ionic, low systemic toxicity and water soluble contrast medium containing organic iodine compounds which is widely used in radiographic procedures. As iohexol passes through the vessels and organs, the flowing pathway is opaque, allowing the visualization of internal structure of abdominal organs such as liver, spleen, kidney and major blood vessels in the canine abdomen. Thus, a high visualize images on canine abdomen can benefit the veterinarian conduct a high accuracy diagnosis to evaluate soft tissue cases including tumors and cysts in the canine cranial abdominal organs. The study was conducted to fulfill the following objective:

- i. To determine the optimum scan delay for post-contrast study using cone beam computed tomography (CBCT) for the various organs in the canine abdomen.

2.0 LITERATURE REVIEW

2.1 Principles of cone beam computed tomography (CBCT)

Cone beam computed tomography (CBCT) is an imaging technique accomplished by rotation of a C-arm gantry where both the radiation source and flat panel detector are fixed (Scarfe & Farman, 2008). The gantry is also known as tube-detector system rotates 360° around the area of interest (Roza *et al.*, 2011). The production of images involved the steps: data acquisition, image detection, image reconstruction and that will be analyzed by a specific computer software program. CBCT produces images with isotropic voxel resolution ranging from 0.076 to 0.4mm, which contributes to high resolution, quality and accuracy for the measurement in clinical applications (Scarfe & Farman, 2008). The scanning systems have been developed for imaging on maxillofacial region in veterinary dentistry as it provides a three-dimensional representative of the oral and maxillofacial skeleton in the many of clinical cases. More recently, the applications have expanding the additional diagnostic applications included radiotherapy guidance. The applications of CBCT also finds helpful in pre-surgical imaging, intra-operative imaging and post surgical evaluation as it provides visualization of three dimensional images of anatomical structures, enable precise surgical guide with anatomical details and improve success rate (John, 2016). The benefit is able to define the precise area with defects and has made CBCT as an imaging modality in the case of trauma, dysfunction, detecting cysts, tumour and calcification.

2.2 Clinical application of cone beam computed tomography (CBCT)

The development of CBCT technique in veterinary dentistry has improved the diagnostic quality in most of the dental abnormalities in feline and canine. It has been used as auxillary exam for diagnosing feline dental resorptive lesion (FDRLs), temporomandibular joint abnormalities, facial trauma, structural maxillofacial deformity, periodontal disease and dental implantation (Roza *et al.*, 2011). Previous studies have also shown that CBCT imaging is able to characterize lesions pertaining to dental abnormalities such as bone fractures, loss radiopacity in the teeth, teeth shape changes, measurement of the area for implantation and also soft tissue surrounding the dental.

CBCT has been used to as an imaging guidance to radiotherapy in many clinical cases. One of the examples is the use of CBCT to characterize daily urinary bladder variations during the treatment of fractionated radiotherapy for bladder cancer in dog (Nieset *et al.*, 2011). The daily motion and positioned changes of the bladder and surrounding soft tissue cause difficulty in calculating adequate dose of radiation therapy. CBCT imaging is used to visualize normal tissue structures before irradiation. This is to ensure adequate radiation dose for bladder dose to minimize irradiation to the nearby healthy tissue.

Overall, CBCT is widely used in dental and skull clinical cases application than soft tissue evaluation except for research purposes due to its limitation in providing high contrast in soft tissue structure details.

2.3 Contrast-enhanced cone beam computed tomography (CE-CBCT)

The most challenging limitation of CBCT is producing a high contrast resolution of soft tissue imaging with current technology. However, the additional of contrast agent can increase soft tissue detection that offers the enhancement of soft tissue visualization and smaller vascular structures. Similarly, a combination of CBCT and intravenous administration of contrast agent can be a diagnostic workup to examine soft tissue lesion in oral and maxillofacial region. According to Kim *et al.* (2015), among the challenges in achieving high-resolution soft-tissue imaging are the limited dynamic range and contrast resolution of current CBCT techniques. They also indicate the use of additional contrast agent may increase the contrast resolution through the application of CBCT (Kim *et al.*, 2015).

A contrast agent is a chemical substance commonly used to contrast the anatomical structures of soft tissue and fluids to enhance visualization of blood vessels and gastrointestinal tract within the body. For safety considerations concern, there is no reporting on adverse effects of non-ionic iodinated contrast such as iohexol in veterinary clinical patients. Therefore, it is relatively feasible, safe and cost effective for veterinary diagnostic imaging. Iohexol is often used exclusively as intravenous CT contrast agent. According to Shanaman, close to 100% of the IV injected iohexol is excreted unchanged through the kidneys within 24 hours in patients with normal renal function. He also suggested no metabolites have been detected and protein binding is very low (Shanaman, 2013). In the past decade, there are a limited number of

publications in veterinary literature on the use of CBCT evaluation of abdominal disease.

In clinical cases, contrast enhanced with CT has been demonstrated in tumour to enhance the tumor from surrounding normal tissue in liver. According to Ghaghada *et al.*, the CT imaging of solid tumour using liposomal-iodine contrast agent in companion dogs with naturally occurring cancer resulted in a significant enhancement and uniform opacification of the vascular compartment. He also suggests that the liposomal-iodine contrast agent is long circulating and able to accumulate in solid tumor, part of enhanced permeability and retention effect have enabled prolonged visualization of small and large tumors in dogs (Ghaghada *et al.*, 2016).

Contrast-enhanced cone beam computed tomography has been studied on its feasibility for target localization and treatment monitoring particularly in image guided radiotherapy (Roda *et al.*, 2010). The imaging with CBCT before and after administration of iodinated contrast agent was performed as the CBCT itself does not provide visually separable of tumour margin to the surrounding normal tissue. The combination of contrast with CBCT imaging is commonly practice in radiotherapy treatment planning to evaluate the appropriate dosage and identify tumour location. Besides, the method can be useful in fractionated radiotherapy to monitor the changes of tumour. The use of contrast may increase the enhancement due to the high tissue perfusion and blood vessels permeability especially in tumour.

3.0 MATERIALS AND METHODS

3.1 Overview

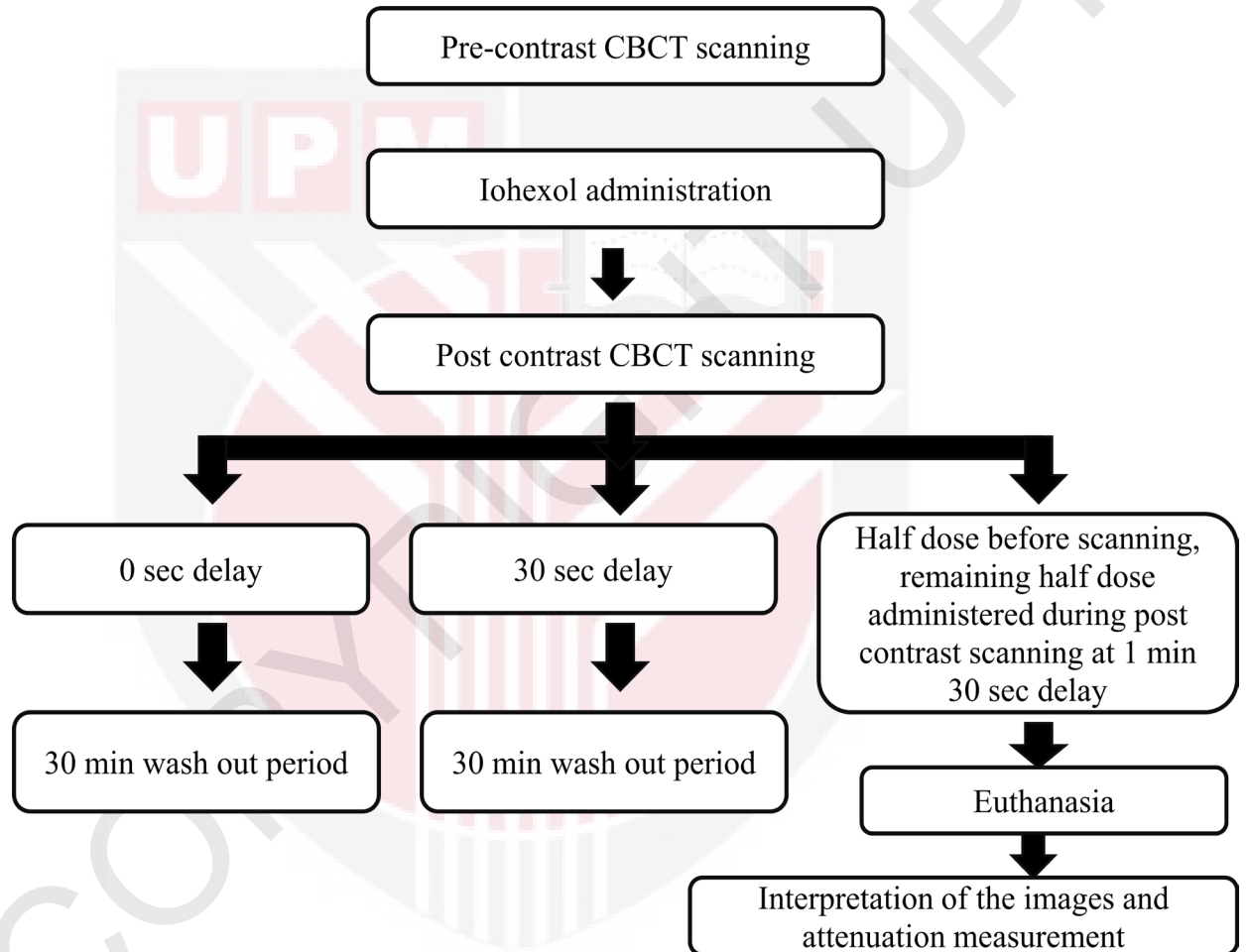


Figure 3.1: A flow chart describing the procedures performed for the study

3.2 Animals studies

A total quantity of 3 adult dogs, local breeds, mixed gender, weighing approximately 15 kg were selected from Dewan Bandaraya Kuala Lumpur (DBKL) and presented to diagnostic imaging department at University Veterinary Hospital (UVH), Universiti Putra Malaysia (UPM). The research was performed as preliminary study to predict the appropriate sample size and establish an optimum scan delay protocol for contrast-enhanced CBCT in the future.

Basic physical examination was performed on each dog and none of the dogs were severely compromised. Each dog was given 18G intravenous catheter placed in cephalic vein in either left or right front limb and secured with plaster tape. Lactated Ringer's solution is given as maintenance rate at 10ml/kg/hr. The dogs participated in the study were sedated and pre-scanned by CBCT prior to the injection of contrast agent followed by post contrast scanning. During the administration of induction agent, the dogs were monitored for heart rate, respiration rate, anesthetic plane and capillary refilled time throughout the procedure.

3.3 Anesthesia protocol

The dogs were induced with Zoletil (tiletamine-zolazepam), at a dosage of 5mg/kg body weight, intravenously to the cephalic vein through the catheter in the front limb. Following induction, the dog was intubated with appropriate size of endotracheal tube and then attached to the anesthetic circuit and oxygen. The cuff was inflated until the leak was sealed. The dog was maintained with isoflurane inhalation anesthesia. The

vaporizer was initially turned on to 2% of isoflurane and dialed at 2-3% during maintenance. The oxygen flow rate was given 1-2 L/min after induction and adjusted to 0.5-1.5 L/min during maintenance for the whole procedure. Chloramphenicol eye ointment was applied to the both eyes to prevent eye dryness during the procedure. The respiration was supported by mechanical ventilator. Deep anesthetic depth was maintained at stage 3 plane 2. If the dogs developed light anesthetic depth with strong jaw tone and high respiration rate, vaporizer will be dialed to 3% until the signs ceased and went into deep plane.

3.4 Contrast administration protocol

Pre-contrast scanning by CBCT was performed prior to the administration of contrast agent. The anesthetized dogs were administered with iohexol at a dose of 800mg/kg body weight slow intravenously infusion for approximately 30 sec via 18G indwelling catheter placing at cephalic vein immediately following the pre-contrast scanning.

3.5 Cone beam computed tomography (CBCT) imaging

The CBCT imaging studies was performed at diagnostic imaging department. All the dogs will be given deep sedation of general anesthetized with tiletamine-zolazepam and maintained with isoflurane as inhalation anesthesia during the whole imaging procedure. The dogs were placed on sternal recumbency position on the scanner table. The head was placing in between the front limbs and both hind limbs were flexed like frog leg position. Imaging studies were performed on FIDEX CBCT

scanner. Pre and post contrast CBCT scans were acquired at 110.0 kV with the following settings: 0.08 mAs per shot, total 59.6 mAs. CBCT captures 512 slices in a single revolution. The reconstructed slice thickness was 0.45mm and the image size 512x512 pixels with pixel size of 1mm. CBCT scanning was done on pre and post contrast for 3-5 minutes. The gantry turned slowly at 10-20 sec per turn. Pre-contrast scanning was done on each dog followed by contrast administration. Post contrast enhancement with CBCT scanning on each dog was done on three scan delay protocols as follow:

- i. Immediately after complete infusion of contrast agent (0 sec delay)
- ii. 30 sec after complete infusion of contrast agent (30 sec delay)
- iii. Half dose contrast before scanning, remaining half administered during scanning at 1 min 30 sec

A 30-min wash out period was observed after the completion of the scan delay protocol of (i) and (ii) and was confirmed with CBCT scanning to ensure the excretion of contrast agent from the circulation before administered the next dose. At the end of scan delay protocol (iii), the dog will be euthanized with pentobarbital at a dosage of 1ml/kg, intravenously.

3.6 Interpretation of images and attenuation measurement

The images acquired were reconstructed and analyzed using FidexGUI. Soft tissue window and transverse view were selected. The images were interpreted at pre contrast, 0 sec delay, 30 sec delay and 1 min 30 sec delay. Among the slice of images, a desirable slice with clear identification and visualization of major blood vessels including descending aorta, caudal vena cava, portal vein; spleen and liver, renal pelvis was selected. Each of the selected images at pre-contrast, 0 sec delay, 30 sec delay and 1 min 30 sec was measured on the attenuation or radio-intensity coefficients in Hounsfield unit (HU).

Thus, identification on blood vessels and organs location was done followed by the measurement of attenuation on various regions of interest. Firstly, descending aorta was measured at the centre as a region of interest (ROI) with a circular shape measurement point, and the value will be displayed on the screen followed by the measurement on caudal vena cava and portal vein. Next, the measurement was done on spleen and liver. However, two ROIs was selected and measured as both organs have larger area. Thus, the average value of two regions measurement point was recorded. As for renal pelvis, however, the slice selected for major blood vessels and organs measurement does not provide visualization of renal pelvis. Hence, to measure renal pelvis, a desirable slice of image was selected with clear visualization of renal pelvis on the left and one slice for the right. One region of interest was done on renal pelvis on both left and right. To standardize the measurement, each and every blood vessels,

organs and renal pelvis at pre to post contrast images of all three dogs will be measured with similar size of circular measurement point and identical region of interest.



4.0 RESULTS

4.1 Qualitative image analysis

The images from CE-CBCT were assessed visually at pre-contrast, 0 sec delay, 30 sec delay and 1 min 30 sec delay. At pre-contrast scanning, there was no clear tissue attenuation observed, making it difficult to identify and differentiate the tissue from one another. However, the location of spleen and liver were recognized although lack of tissue margin. However, at 0 sec delay, contrast enhancement was observed in blood vessels without clear tissue margin. Spleen and liver were observed with clear tissue margin and kidney was observed to pick up the contrast on the same slice. At 30 sec delay, a better contrast enhancement of tissue margin was observed on descending aorta, caudal vena cava, portal vein, liver and spleen. The kidney was significantly contrast enhanced. Similarly, the contrast enhancement of 30 sec delay is comparable with 1 min 30 sec delay with clearly visualization of both blood vessels and organs.

As for the renal pelvis in different scan delay images, pre-contrast scanning does not provide visualization of renal pelvis. However, at 0 sec delay, mild contrast enhancement was observed on the renal pelvis although the structure was unclear. At 30 sec delay, better contrast enhancement was observed on renal pelvis and it was similarly contrast enhanced at 1 min 30 sec delay.

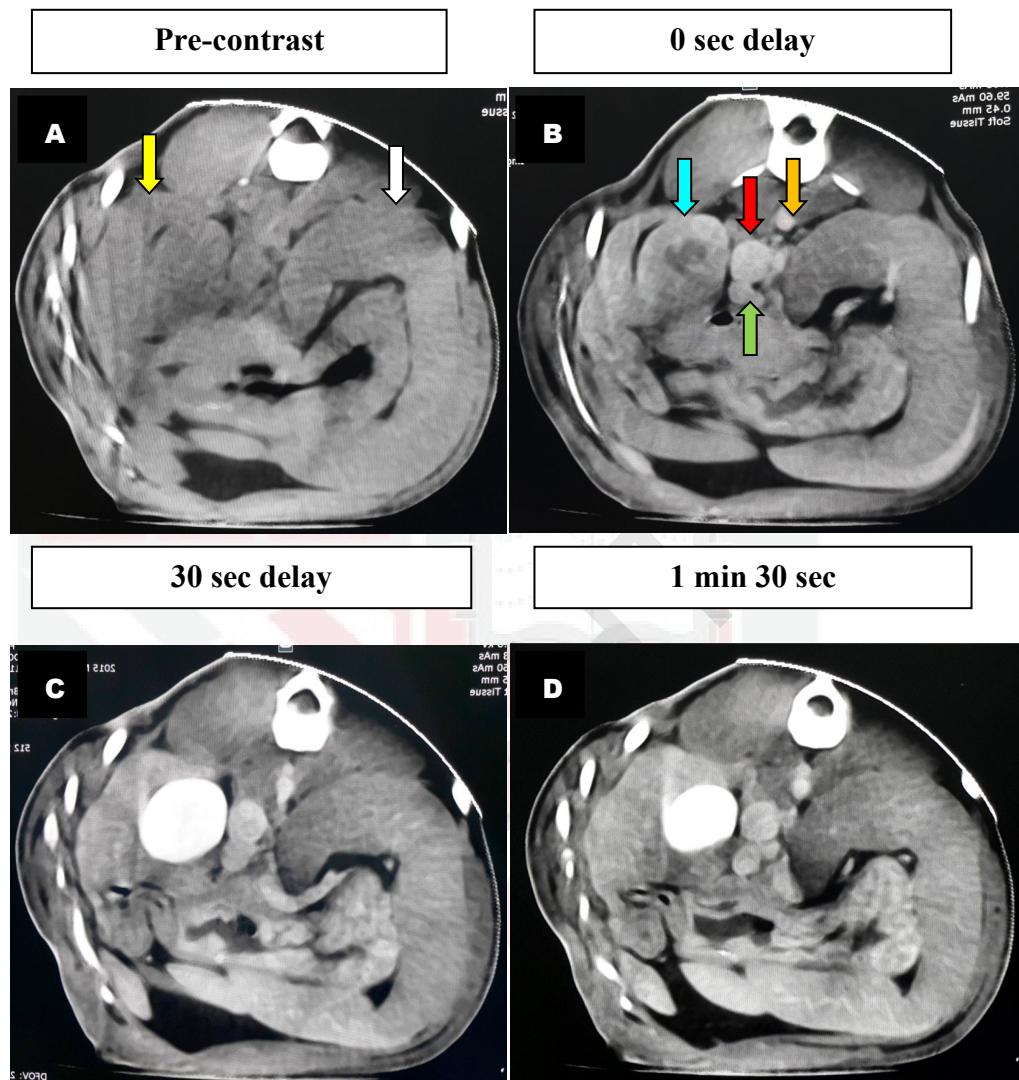


Figure 4.1: Contrast enhancement pattern in blood vessels and organs of dog 1. (A) Non-enhanced CBCT image showing liver (yellow arrow) and spleen (white arrow). (B) Blood vessels: aorta (orange arrow), caudal vena cava (red arrow), portal vein (green arrow) and kidney (blue) enhanced are visible at 0 sec delay. (C) The blood vessels and organ are better visualized with increased kidney uptake of contrast agent at 30 sec delay. (D) Similar enhanced image with 30 sec delay.

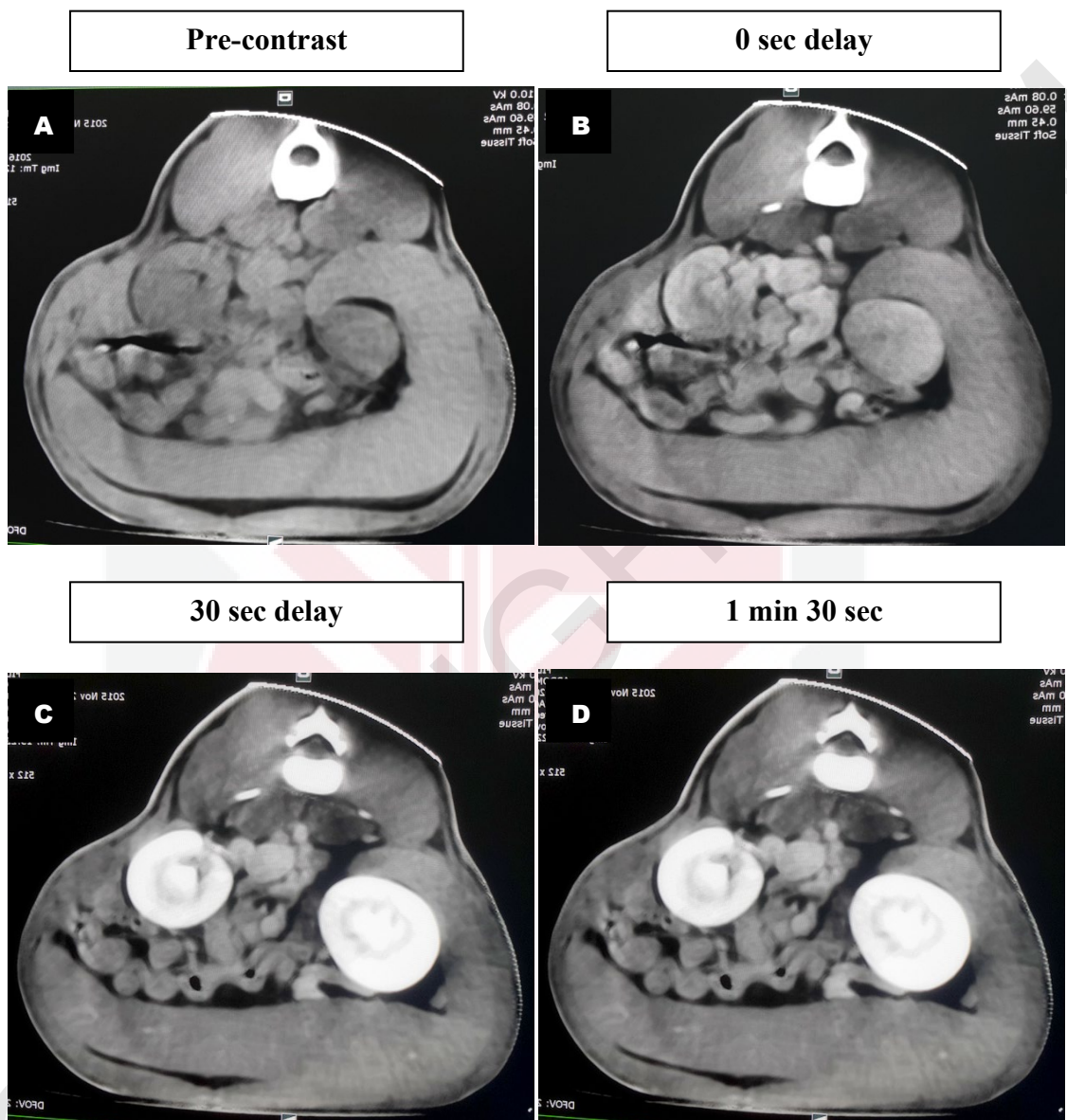


Figure 4.2: Contrast enhancement pattern in renal pelvis of dog 1. (A) Non-enhanced CBCT image does not provide visualization of renal pelvis. (B) Mild contrast taken up by renal pelvis. (C) Better visualization of renal pelvis with high uptake of contrast by kidney. (D) Similar contrast enhancement as 30 sec delay.

4.2 Quantitative image analysis

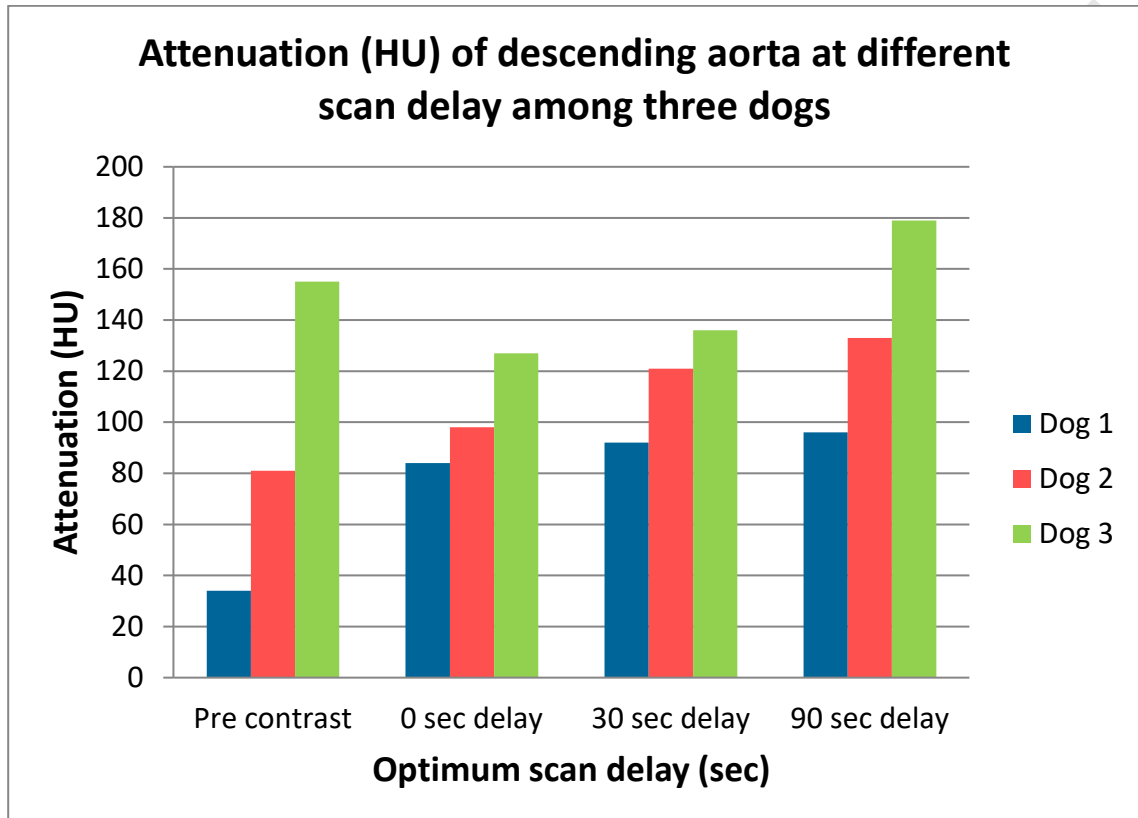


Figure 4.3 Attenuation (HU) of descending aorta at different scan delay among three dogs.

The attenuation value at pre-contrast could be lower than post contrast attenuation at different scan delay except for Dog 3 which is outlier with high attenuation value at pre-contrast compared to other dogs (Figure 4.3). Generally, the pattern for elevation was observed from pre to post contrast enhancement imaging. The attenuation at 0 sec delay and 30 sec delay was comparable.

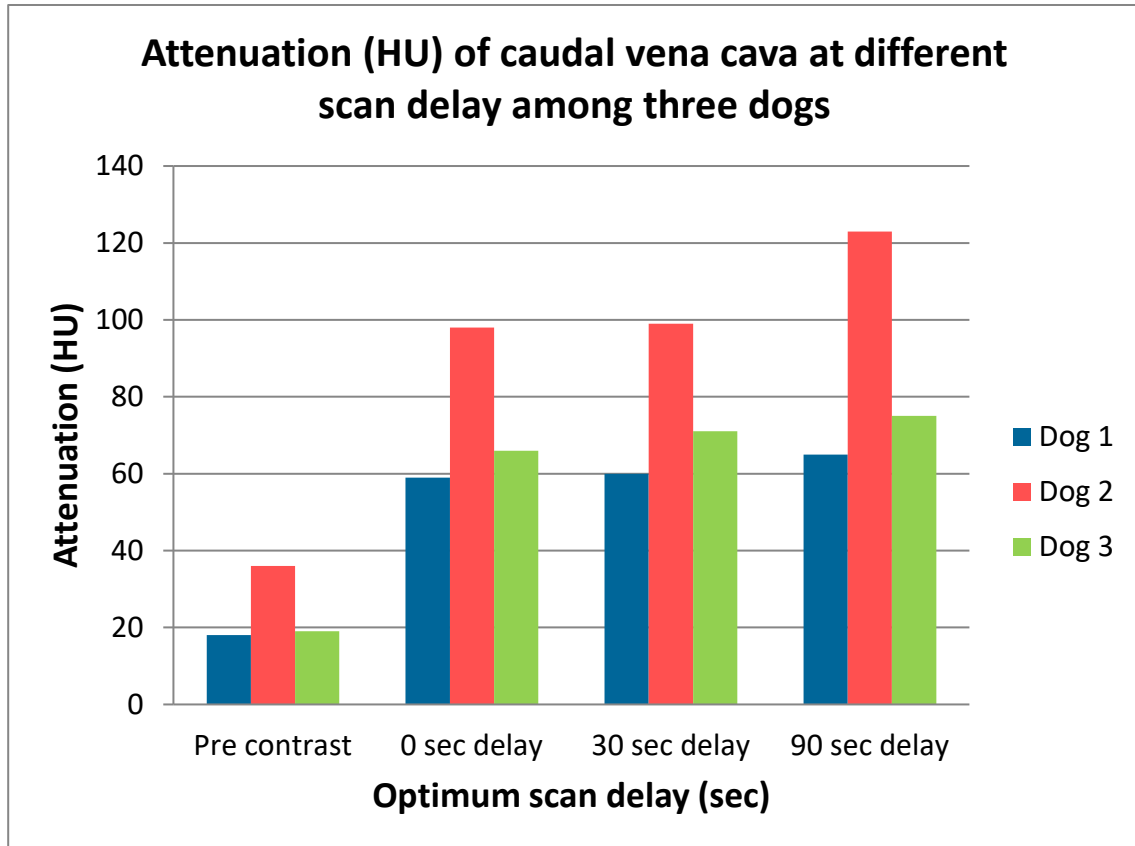


Figure 4.4 Attenuation (HU) of caudal vena cava at different scan delay among three dogs.

The pattern of elevation was steady from pre to post contrast at different scan delay in caudal vena cava (Figure 4.4). Similarly as aorta, the elevation pattern at 0 sec and 30 sec are almost similar. However, 1 min 30 sec delay provide slightly better contrast enhancement than 0 sec and 30 sec delay. The attenuation value in dog 2 was higher among others from pre to post contrast.

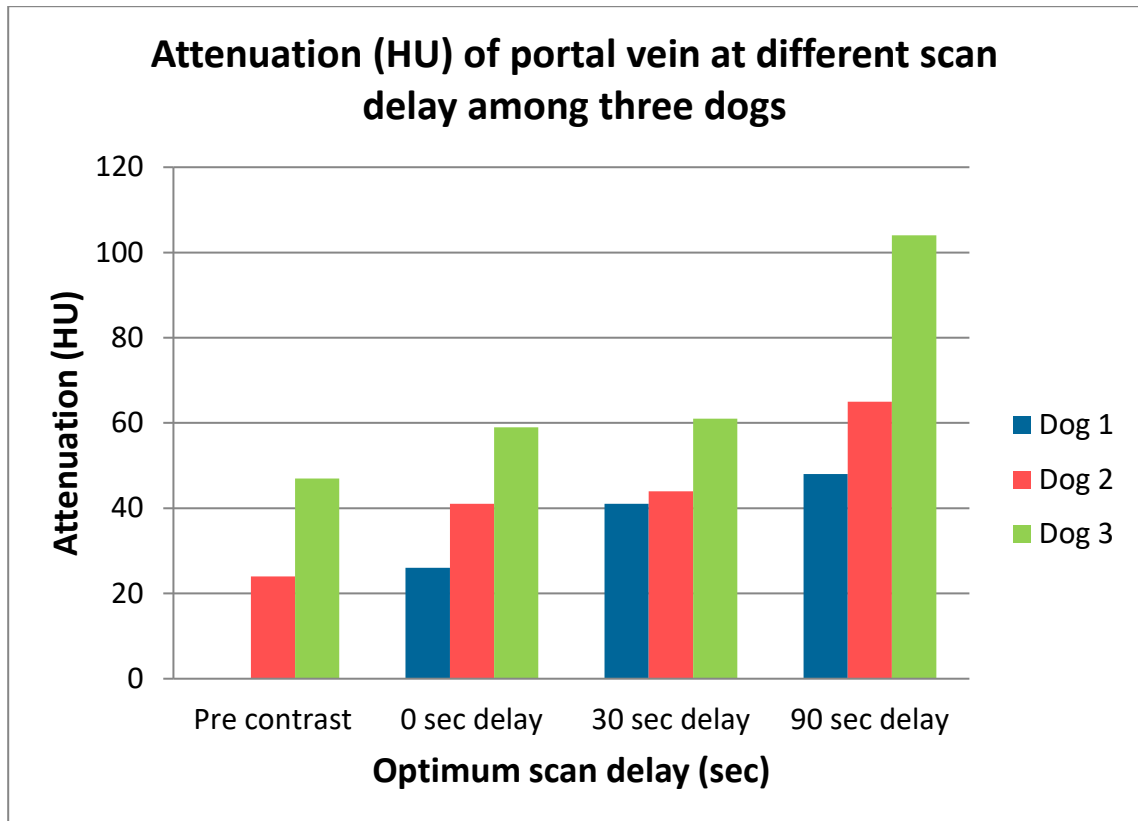


Figure 4.5 Attenuation (HU) of portal vein at different scan delay among three dogs.

As for the portal vein, the pattern of elevation was observed from pre to post contrast. At pre contrast, there is no value in dog 1 as the portal vein location was not visible and could not be identified. However, it has similar elevation pattern elevated steadily from pre to post contrast. Obviously, 1 min 30 sec provided the highest attenuation or contrast enhancement among the others.

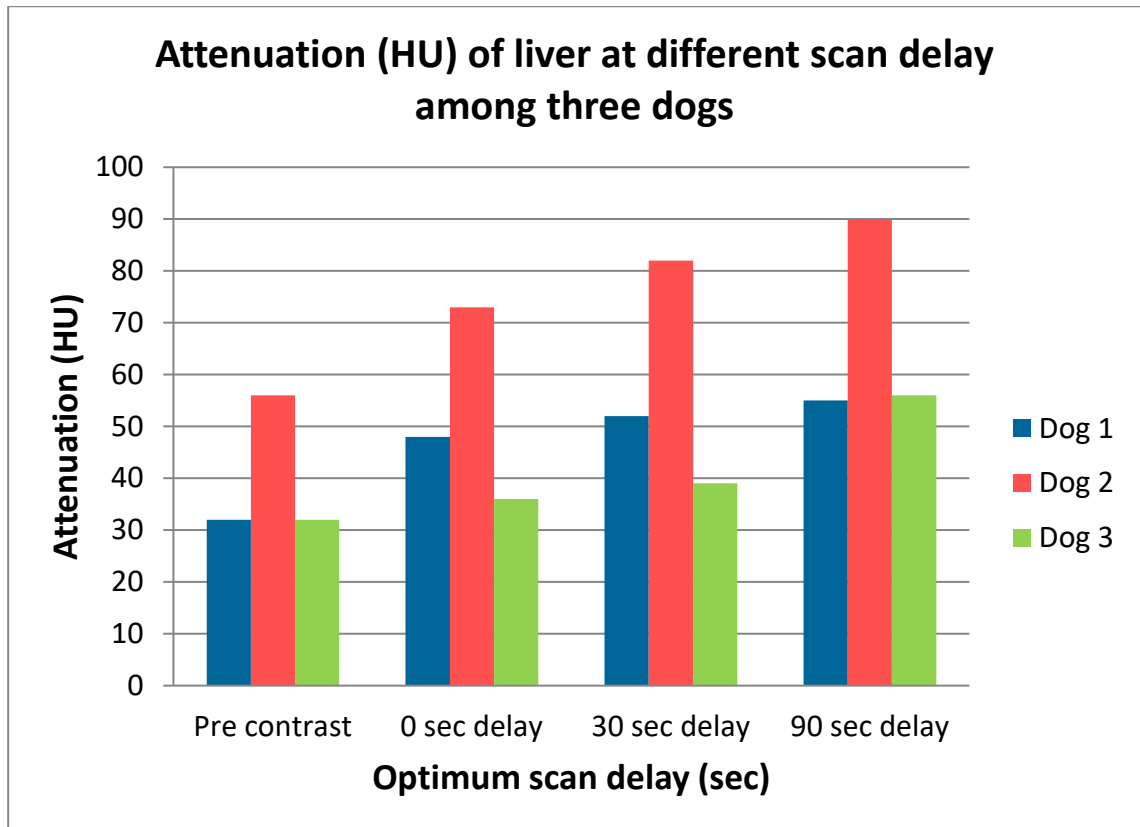


Figure 4.6 Attenuation (HU) of liver at different scan delay among three dogs.

The figure 4.6 above shows the attenuation value of liver. A pattern elevation of attenuation was observed from pre to post contrast which is similar as major blood vessels. However, as shown in the figure, the attenuation value in Dog 2 was higher compared with others from pre to post contrast.

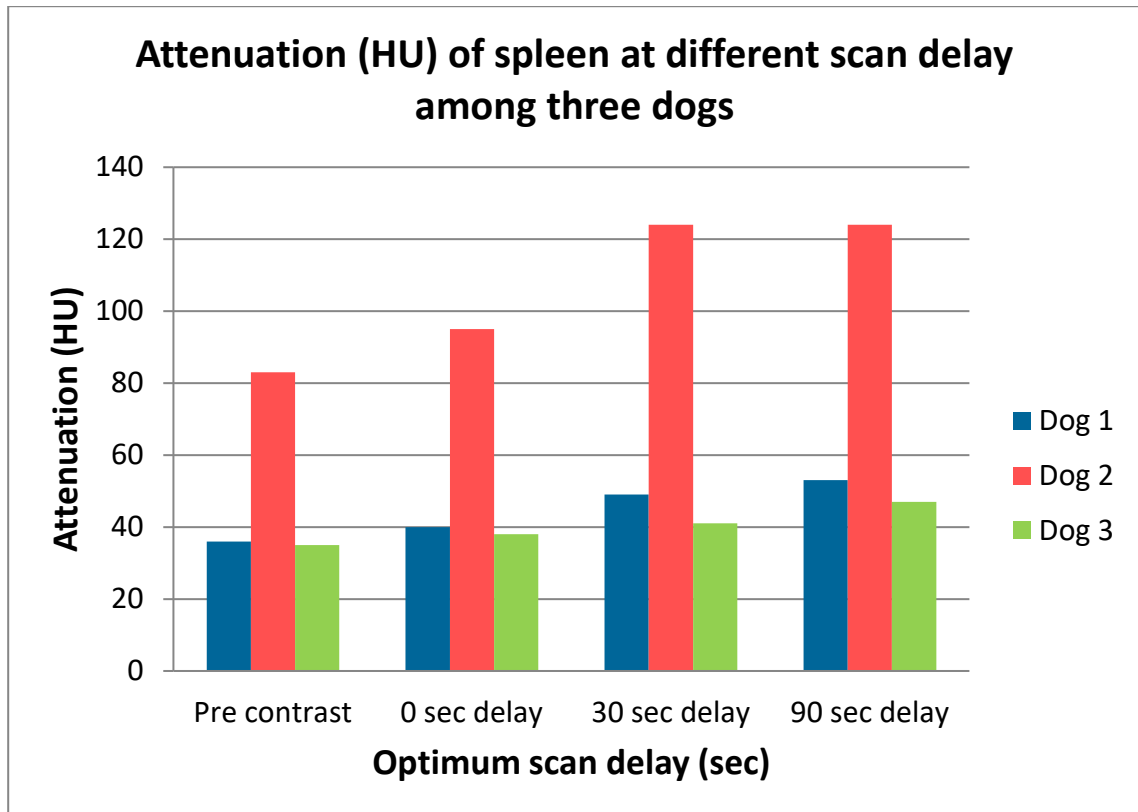


Figure 4.7 Attenuation (HU) of spleen at different scan delay among three dogs.

However, as shown in the Figure 4.7, the variation of the spleen attenuation in dog 2 is prominent compared with other dogs. Other than that, the graph shows steady elevation of attenuation. Also, the attenuation at 30 sec is comparable with 1 min 30 sec.

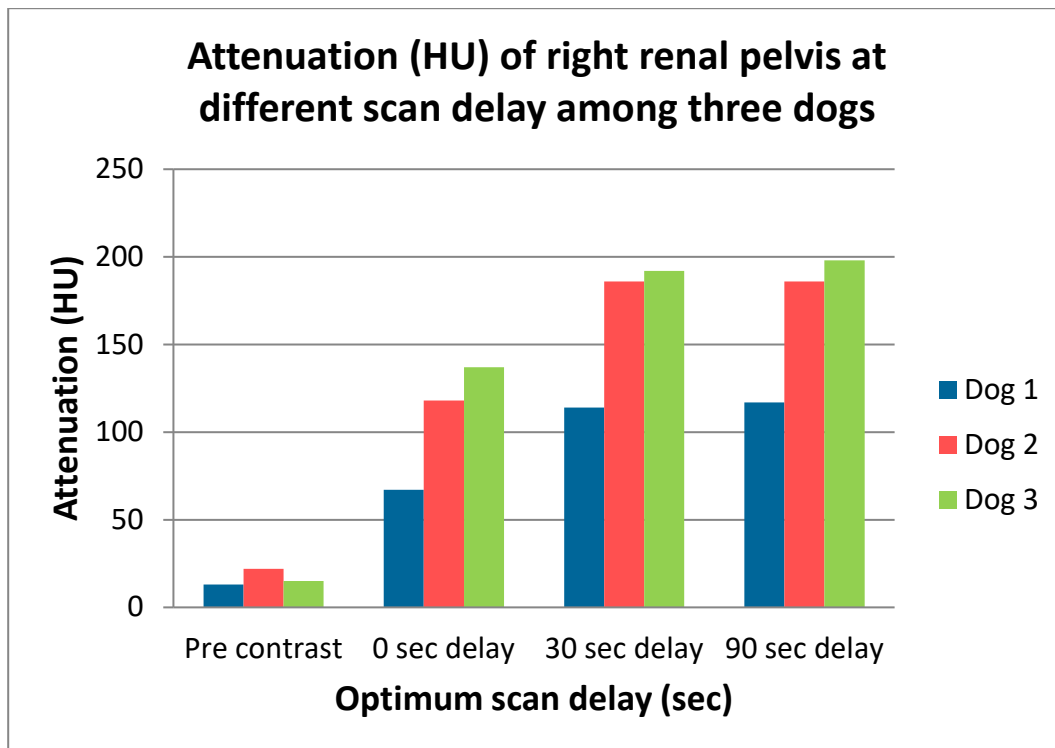


Figure 4.8 Attenuation (HU) of right renal pelvis at different scan delay among three dogs.

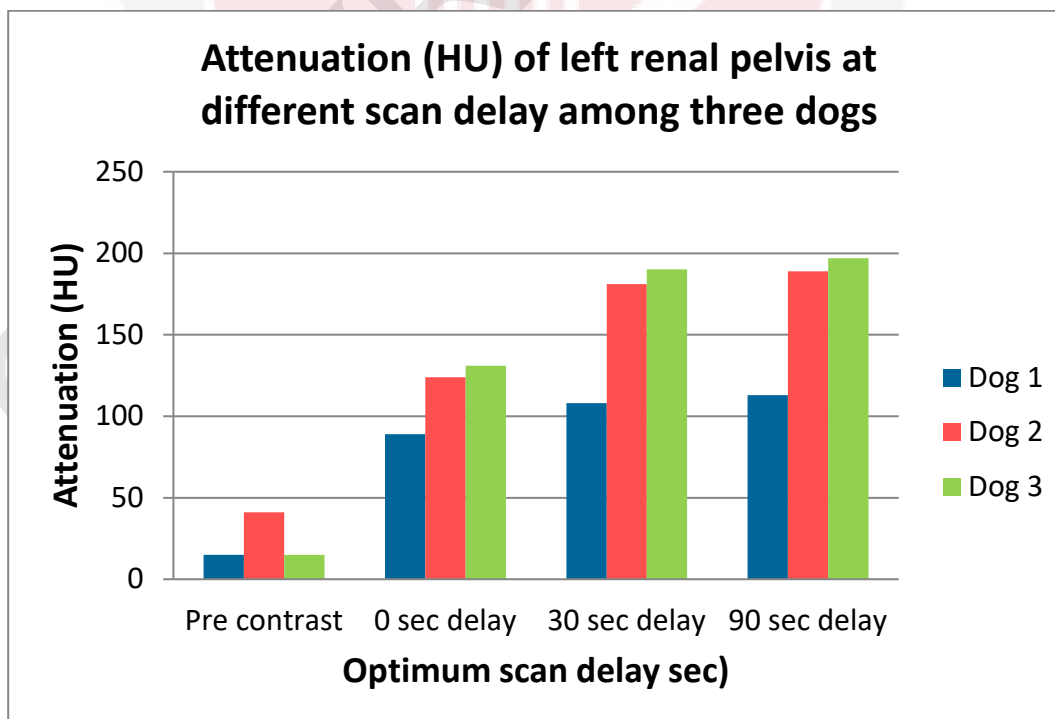


Figure 4.9 Attenuation (HU) of left renal pelvis at different scan delay among three dogs.

As shown in the figures above, the result of right renal pelvis is comparable with left renal pelvis. Both right and left renal pelvis showed steady elevation of attenuation. At 30 sec, the attenuation was similar as with 1 min 30 sec on the both left and right renal pelvis.



5.0 Discussion

5.1 Subjective and objective enhancement comparison

Previous studies assessing the scanning delay of contrast administration in CBCT imaging and visualization of contrast in soft tissue were limited. Hence, the present study was performed to evaluate optimum scan delay for post contrast-enhanced CBCT in canine abdomen organs and major blood vessels to increase visibility of vascular structures and organs details.

Our investigation indicated that post-contrast imaging in major blood vessels and abdominal organs were successfully contrast enhanced as shown in the figures. Gradual contrast enhancement was observed from pre to post contrast images. The contrast flowed in blood circulation and taken up by the subject interests thus increased the radio-intensity of any tissue that the contrast passed and accumulated on it. The major blood vessels and abdominal organ were therefore clearly distinguishable on the images with contrast-enhanced imaging at different scan delay.

The contrast agent taken up by organs or blood vessels interest will provide high contrast intensity or attenuation value and it will be measured as Hounsfield unit. Hence, the higher the contrast intensity will give higher attenuation value (HU) as well. The attenuation coefficients in abdominal organs were all elevated from pre to post contrast imaging. Thus, post contrast imaging was successful contrast enhanced in abdominal organs. At 0 sec and 30 sec scan delay, the attenuation values were almost identical for aorta and caudal vena cava. However, the subjective and objective

enhancement comparison between aorta and caudal vena cava were inconsistent as the imaging at 0 sec delay did not provide clear tissue margin and details as clear as 30 sec delay whereas the attenuation values in both blood vessels were comparable. For this reason, it can be caused by the variation between individual and patients related motion artifacts which could affect the variation in attenuation value as well. As for the liver and spleen, both organs were better visualized at 30 sec and 1 min 30 sec delay whereas renal pelvis on both right and left side have marked contrast enhancement at 30 sec and 1 min 30 sec delay. Therefore, the result of attenuation value in liver, spleen, right renal pelvis and left renal pelvis were consistent with subjective evaluation.

Therefore, the optimum scan delay from the comparison of subjective and objective enhancement evaluation is 30 sec delay as the scanning timing could provide contrast enhanced tissue with details margin and structures. Although 30 sec delay and 1 min 3 sec delay do provide the similar contrast enhancement subjectively and objectively, 30 sec delay is suit for the scanning timing due to the safety issue related to contrast administration at 1 min 30 sec delay.

5.2 Factors affecting post contrast imaging quality

In this study, patient motion artifacts can cause unsharpness in the reconstructed images, affecting attenuation measurement values. Therefore, breathing control with ventilator and anesthetic plane monitoring is crucial to reduce horizontal streaking artifacts on the images during scanning. This is because the streaking artifacts would give a higher attenuation values and higher variation between individuals.

Contrast enhancement can be affected by patient related factors including body weight and underlying disease. In the study, the body weight of each dog was not exact 15 kg but approximately between 14 to 16 kg. As the body weight can be associated with blood volume, tissue volume and tissue composition individually. As a larger patient is consistent with larger blood volume than small patients, the contrast enhancers administrated in the blood circulation could dilute the contrast concentration and lower contrast enhancement. Similarly in obese individual with higher fat tissue, the contribution of contrast agent will be reduce as well as the dilution of contrast due to less vascular of fat tissue. Thus, the amount of the volume should be adjusted for body weight to achieve a consistent contrast enhancement.

Other than that, patients with underlying disease and dehydration could affect the contrast distribution and absorption as well. As the contrast agent targets on the blood plasma and organs for greatest absorption, the high uptake of contrast is well-dependent on great tissue perfusion and permeability. Dehydration can cause decrease in water and affect absorption and perfusion rate of the water soluble contrast medium.

Hence, it is important to assess the dehydration status prior to contrast administration for CBCT. Age is also likely related to the contrast enhancement timing. In old patients the cardiac output and cardiovascular circulation is reduced, causing slower circulation of contrast to the target tissue, resulting delayed contrast medium arrival and also slower in clearance from the circulation. Poor organ functionality with underlying disease especially in high vascularized tissue such as spleen, liver and cardiac would affect the contrast absorption rate by the organs. As the organs are unable to function efficiently, the absorption of contrast will be lower than the normal rate which later will interfere the enhancement magnitude of the target organs.

Overall, the attenuation value in this study was affected by the motion caused artifacts. As the artifacts produced on the images were appeared as high intensity of streaking marks that have interfered the attenuation measurement result. Besides, the motion artifacts could be caused by anesthetic plane that should be monitored in deep plane as light or medium plane could affect the motion-caused factor individually. Hence, frequent monitoring on the heart rate and respiration rate are required for the adjustment of vaporizer to ensure the dog was in deep plane to reduce motion artifacts especially during scanning.

5.3 Benefits and limitations of cone beam computed tomography (CBCT) imaging

CBCT imaging technique is an alternative method to achieve cross sectional images. The development of the technique by performing CBCT scanning with intravenous administration of contrast agent has improved the imaging quality. One of the great advantages of CBCT is that the imaging equipment is cost-effective compared to MSCT. It is approximately one quarter to one fifth of the cost of conventional CT (Scarfe & Farman, 2008). Besides of being considerably smaller and lighter, it has no special electrical requirement, space-saving and easy to operate and to maintain which requires little technician training. Moreover, the imaging system provides a shorter examination time, reduction of image unsharpness, reduction of image distortion due to motion effects. CBCT scanning time is shorter as it acquires all projection images in a single rotation and hence the motion artifact of the subject is reduced as well. The deliver dose of irradiation to patients is minimal as the collimation of primary x-ray beam enables the limitation of radiation to the area of interest with an optimum field of view. Therefore, it is increasing popular in most clinical practices with high diagnostic capability and lower radiation dose in dentomaxillofacial imaging which make the work easier, precise and reliable.

However, CBCT imaging for soft tissue resolution is limited to provide visibility of vascular structures and the surrounding tissue. One major disadvantage of CBCT is that it can only demonstrate limited contrast resolution due to detection of scattered radiation during image acquisition process. If the objective of the examination is hard tissue only, using a CBCT would not be a problem; however, CBCT is not sufficient for soft tissue evaluation (Adibi *et al.*, 2012). The highly contrasting of hard tissue structure is therefore well suited for the maxillofacial imaging.

The limitation of the preliminary study on the evaluation of optimum timing for post-contrast CBCT scanning was small sample size. To validate the current result of 30 sec delay as optimum timing for post contrast imaging, a larger sample size is required with statistical analysis for the future study.

6.0 Conclusion

Overall, the combination of intravenous contrast administration for CBCT scanning is useful for soft tissue evaluation particularly in major blood vessels and abdominal organs. The optimum timing for post contrast CBCT imaging is established at 30 sec as recommended for multiple abdominal organs and blood vessels study due to the safety issue related to contrast administration. Thus, the objective of the study to evaluate the optimum scanning delay protocol for post-contrast CBCT has been accomplished. Therefore, the optimum scanning protocol in this preliminary study can be used for further study in the future. However, larger sample size to validate the current result is required to achieve a high reliability diagnostic value of scanning protocol for contrast enhanced study in soft tissue.

7.0 Recommendations

Area of interests Scan delay timing	Descending aorta	Caudal vena cava	Portal vein	Liver	Spleen	Renal pelvis
Pre-contrast				√	√	
0 sec delay	√	√	√	√√	√√	√
30 sec delay	√√	√√	√√	√√√	√√√	√√
1 min 30 sec delay	√√	√√	√√	√√√	√√√	√√

Table 7.1 Scan delay timing protocol subjects to the area of interest

The table above shows the general recommendation on the scan delay timing subjects to the area of interests. At pre-contrast scanning, there is tissue attenuation on liver and spleen in which the location is visualized but without clear tissue margin, making it less valuable for evaluation. At post-contrast 0 sec imaging, contrast enhancement can be observed on blood vessels and renal pelvis but lack of tissue margin visibility. However, spleen and liver margin can be visualized. In comparison with 30 sec delay, the contrast enhancement is better visualized in blood vessels and abdominal organs. Thus, it is sufficiently applicable in most clinical cases involving spleen and liver tumors, hemangiosarcoma, and portal systemic shunt. As for 1 min 30 sec the contrast enhancement is comparable with 30 sec delay. However, we would like to recommend 30 sec delay as an optimum scan delay for post contrast CBCT scanning due to safety issue concerning to the contrast administration.

8.0 References

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