OPTIMIZATION OF A NOVEL HEPATOBILIARY SCINTIGRAPHY PROTOCOL

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TITLE: Optimization of a Novel Hepatobiliary Scintigraphy Protocol

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Abbreviations: Hepatobiliary iminodiacetic acid (HIDA), gallbladder ejection fraction (GBEF), gastric emptying (GE)

Key Results: Potential revenue generated by preforming more scans per day using the novel protocol increased from a gross income per day of $2840.00 for the base model to a theoretical $19,880.00 per day. Gross income per year for stacked HIDA scans increased from $741,240.00 to a maximum theoretical gross per year of $5,188,680.00. Total time ranged from 6.57 hours per day to 8.87 hours per day.

Summary Statement: **The study provides customizable models using a novel hepatobiliary scintigraphy protocol that can be implemented to enhance imaging center workflow and revenue, and provide more quality and efficient care.**

ABSTRACT
Strategic use of medical imaging can improve healthcare quality and reinforce the practice of precision medicine by providing specific, individualized diagnostic information. Unfortunately, excessive radiologic scan duration times limit imaging center efficiency, leading to decreased patient satisfaction and heightened facility costs. A novel hepatobiliary scintigraphy protocol outlined by Verma et al. can be utilized with equivalent diagnostic ability to maximize scanner operation. The current study demonstrated multiple ways in which the new scintigraphy protocol can be optimized to increase imaging facility productivity. The models presented allow for customization based on facility preference and capability in order to decrease costs and generate revenue, while improving patient satisfaction.

INTRODUCTION

Medical imaging is a critical element of the practice of medicine. A major drawback to medical imaging is the time-consuming nature of many of the scans. One nuclear medicine study that has historically required a more lengthy duration is hepatobiliary scintigraphy, commonly known as the hepatobiliary iminodiacetic acid (HIDA) scan. HIDA scans allow visualization of the biliary tract as well as evaluation of hepatocellular and gallbladder function. The procedure requires intravenous injection of a biliary-excreted radiotracer followed by intravenous injection of a synthetic cholecystokinin analog. Typically, image acquisition begins prior to tracer injection and continues dynamically for a duration of 120 minutes. Flow of bile through the hepato-biliary system is evaluated via direct visualization of tracer within the liver and biliary tree, as well as by calculation of the gallbladder ejection fraction (GBEF). Decreased GBEF and delayed tracer clearance indicate biliary tract pathology. In this way, HIDA scans are a highly useful tool that can be used to evaluate biliary tract structure and function.

While HIDA scans play a valuable role in evaluating the biliary tree, each scan is lengthy in duration and requires a significant time commitment from patients and imaging facilities. This places a sizeable burden on patients, and monopolizes the use of the nuclear medicine scanner, thereby limiting the capacity of the imaging facility. Imaging centers are therefore restricted by time restraints that permit only a few hepatobiliary scintigraphy studies per day.

The traditional method of hepatobiliary scintigraphy was challenged by Verma et al., who demonstrated that serial static image acquisition is equally effective in determining calculated GBEF percentages as dynamic image acquisition (2017). Using serial static image acquisition, hepatobiliary scintigraphy can be optimized to require only 10 minutes of total camera time as opposed to 120 minutes of continuous imaging. This promoted the development of a novel HIDA scan protocol that involves serial 2-minute long static image acquisitions at 15, 30, 60, 90, and 120 minute time points following tracer injection. The shift from dynamic to serial imaging creates significant open scanner time within the HIDA protocol that can be optimized to allow maximization of patient satisfaction and equipment utilization. The current study aims to analyze the workflow of nuclear medicine studies utilizing the serial static image acquisition methodology of hepatobiliary scintigraphy to optimize scanner utilization, patient comfort, and income potential.

METHODS

Using the HIDA scan protocol outlined by Verma et al., multiple theoretical models were created to maximize open scanner time utilization. First, the protocol was expanded to determine the maximum number of HIDA scans that could be run simultaneously by staggering scans within open scanner time between images. This required stacking the scans so that each scan would occur immediately after completion of the previous patient's scan. Specifically, acquisition of image one for Patient One occurred at the 15-minute time point for a duration of two minutes; image one for Patient Two occurred at the 17-minute time point; image one for Patient Three occurred at the 19-minute time point, and so on (Model 1).

In order to establish a more feasible model, time was added to the base imaging model (Model 1) to allow for transition time between image acquisitions. Transition time is defined as time allotted for patient transfer on and off the scanner. This included addition of one minute increments of transition time to the beginning and end of each image, sequentially (Models 3-8).

Using Models 3-8, a transition time of three minutes was selected for the purpose of future analysis (Model 6), allowing for two minutes for positioning the patient on the scanner and one minute for the patient to exit. Model 6 was selected as it provided a maximum ratio of transition time to number of patients imaged. This base model was then modified and expanded to include other imaging studies of varying duration.

First, potential optimization of stacked HIDA scans with other nuclear medicine imaging studies was investigated. This was accomplished by inserting additional nuclear medicine imaging studies within remaining open scanner time, beginning with the addition of Gastric Emptying (GE) studies, as shown in Model 9. The remaining time was generalized to accommodate additional 20-minute nuclear medicine studies (Model 10).

Next, the protocol open scanner time was optimized for one HIDA scan at a time, keeping with the three-minute transition time between images (Model 11). In this model, 20-minute studies were added to the open scanner time of one HIDA scan.

Finally, a single HIDA scan was considered with stacking multiple other imaging studies, including GE studies as well as various 20 minute nuclear medicine studies (Model 12).

Revenue was then analyzed, starting with stacked HIDA scan models. Minutes per cycle of each model were totaled and multiplied by the maximum number of HIDA scans that can be run using the standard 120-minute protocol in a nine-hour day, which was rounded to four scans per day. This gave a value for total scan time in hours per day. Next, HIDA scan revenue was estimated using Medicare data based on CPT codes, which designated a cost of $710 per scan. That revenue was then multiplied by the number of scans per cycle and cycles per day to determine gross revenue estimates per cycle and per day, respectively. Those estimations were extrapolated to estimate gross revenue per day and per year. These findings are outlined in Table 2.

Revenue for stacked HIDA scans with other nuclear medicine studies models were evaluated by following the same format. Estimated gross income per cycle was calculated by totaling the revenue of each scan multiplied by the number of scans per cycle. The previous method was utilized to extrapolate gross revenue per day and per year for the stacked HIDA plus other study models. These data are included in Table 3. The process was then repeated to extrapolate gross revenue per day and per year for single HIDA study plus other GE and 20-minute study models (Table 3). For calculation purposes, Follow Up Bone Scan study was chosen as the 20-minute procedure as it is a common nuclear medicine study. Bone scan revenue was estimated using Medicare data based on CPT codes, which designated a revenue of $514 per scan.

RESULTS

Models

Table 1 shows an outline of each model with respective scan numbers and transition times.

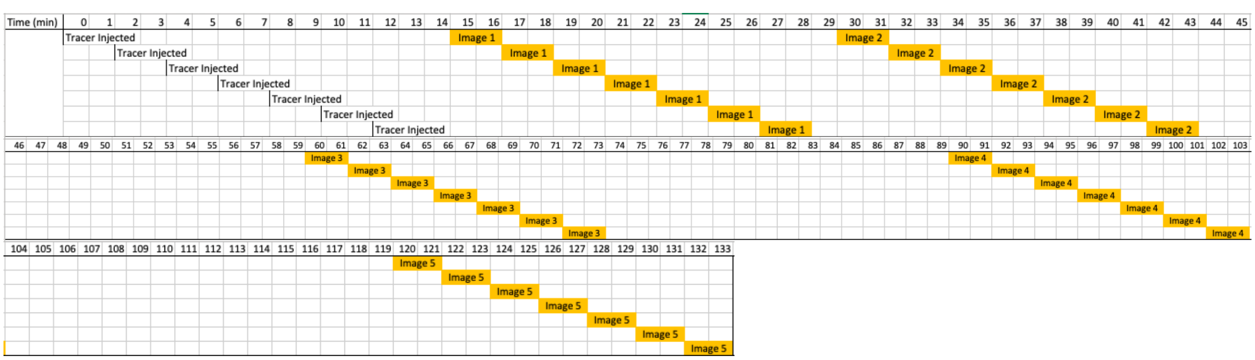
Table 1: All Models

Model #	Scans	Transition time (min)
1	7 HIDAs	0
2	6 HIDAs	0
3	5 HIDAs	1
4	4 HIDAs	1
5	3 HIDAs	2
6	3 HIDAs	3
7	2 HIDAs	4
8	2 HIDAs	5
9	2 HIDA + 2 GEs	3
10	2 HIDA + 2 GEs + 2 Bone Scans	3*
11	1 HIDA + 3 Bone Scans	3 to 8
12	1 HIDA + 4 GEs + 3 Bone Scans	3 to 4

*Model 10 includes 3 minutes of transition time, with the exception of one minute of transition time before each 20-minute study.

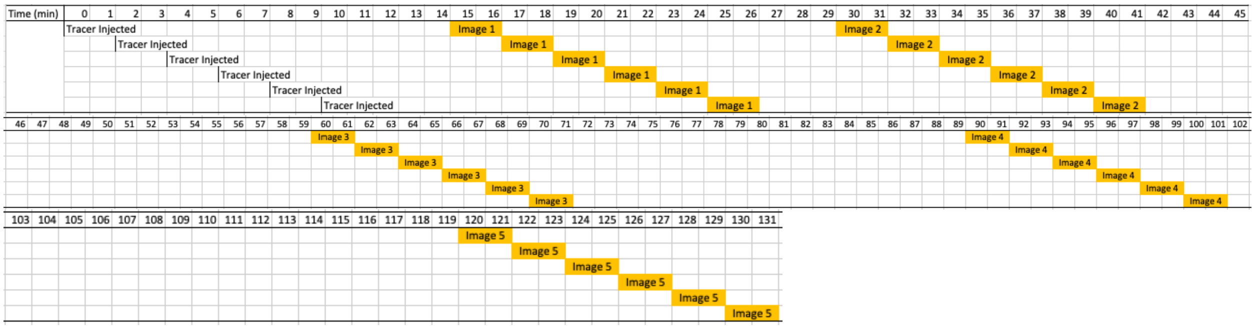
The imaging models are outlined in Models 1-9, shown below. As seen in Model one, open scanner time optimization was limited by the timing of the first and second image acquisitions, as image one for Patient Seven would end at minute 29, and image 2 for Patient One must occur at minute 30 (Model 1). Additionally, the base model allowed 15 minutes between acquisition of images 2 & 3, 3 & 4, and 4 & 5. The 15 minute open scanner time was not enough time to run an additional cohort of scans at time point 44, as the second image would interfere with acquisition of the first cohort's third image.

Model 1: Seven HIDA scans. Image time indicated in first row, with image acquisition times highlighted in yellow. Each row indicates a single patient (1 HIDA scan).



Model 2 outlines six simultaneous HIDA scans. It was not possible to add transitional time to six or seven scans running simultaneously, as the transition time would have impacted the acquisition of image two of the first scan in both models (Models 1 & 2).

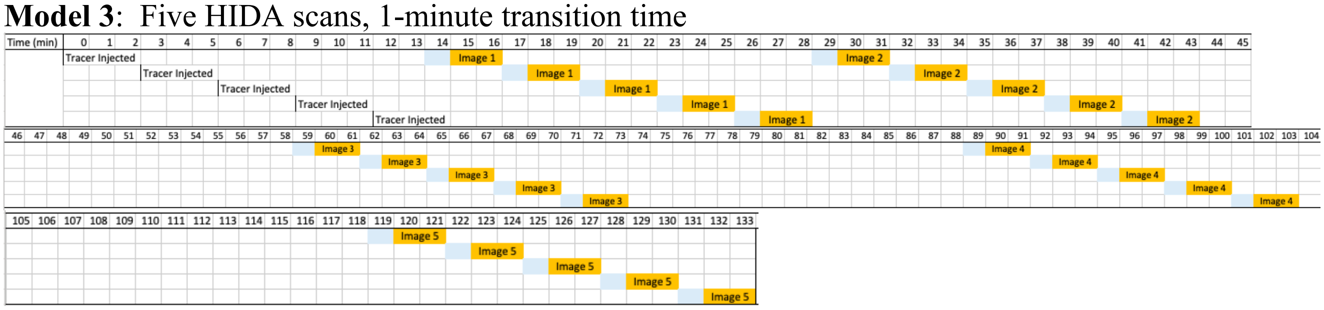
Model 2: Six HIDA scans



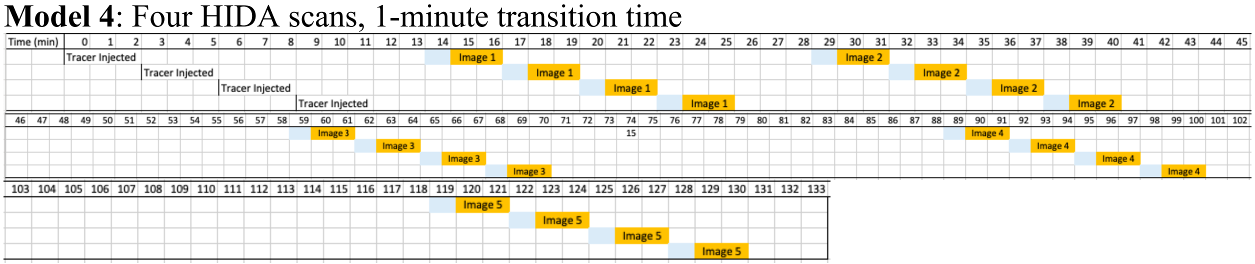
Models 3-8 include stacked HIDA scans with variable transition times. One minute of transition time would allow for five or four patient scans to run at the same time (Models 3 and 4, respectively). Two and three minutes of transition time allowed for three scans to run at the same time (Models 5 and 6, respectively), and four and five minutes allowed for two scans to run simultaneously (Models 7 and 8, respectively).

Model 3-8: Image time indicated in first row, with image acquisition times highlighted in yellow, transition time highlighted in blue. Each row indicates a single patient (1 HIDA scan).

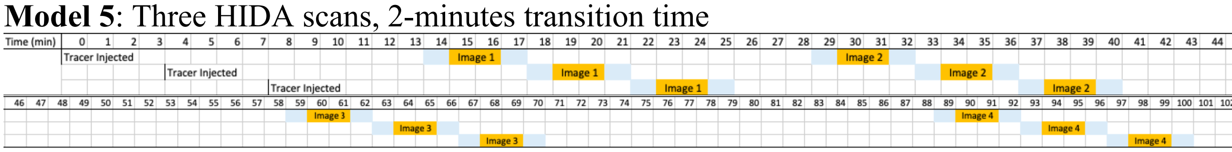
Model 3: Five HIDA scans, 1-minute transition time

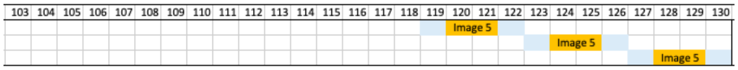


Model 4: Four HIDA scans, 1-minute transition time

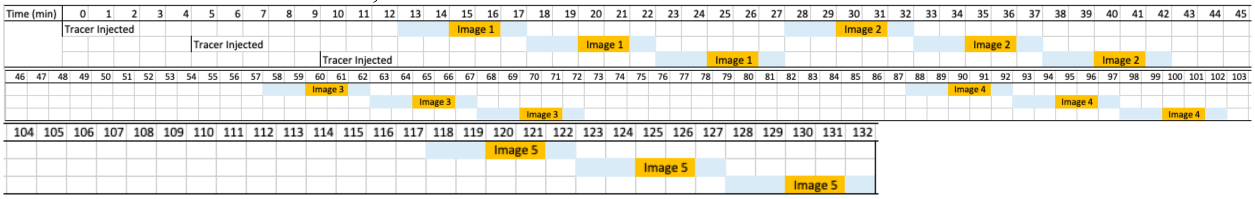


Model 5: Three HIDA scans, 2-minutes transition time

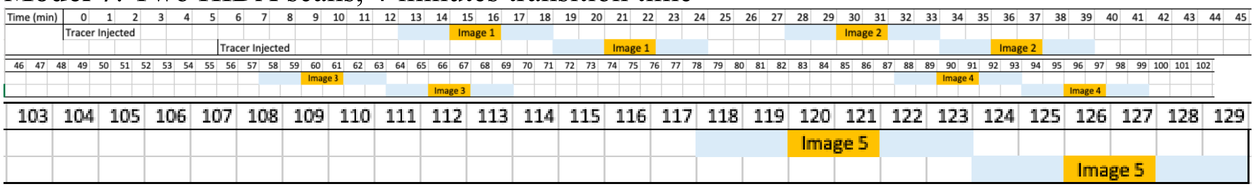




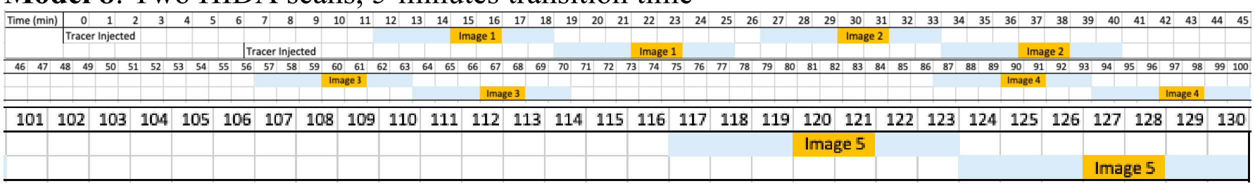
Model 6: Three HIDA scans, 3-minutes transition time



Model 7: Two HIDA scans, 4-minutes transition time

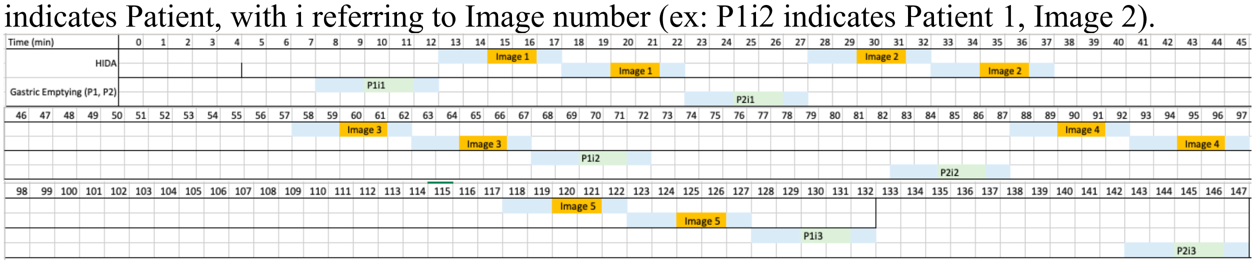


Model 8: Two HIDA scans, 5-minutes transition time

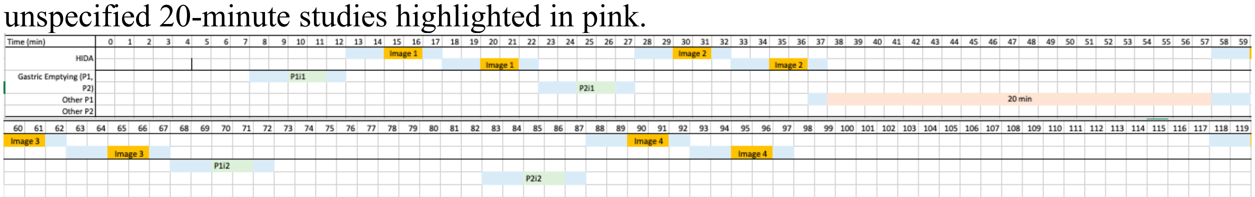


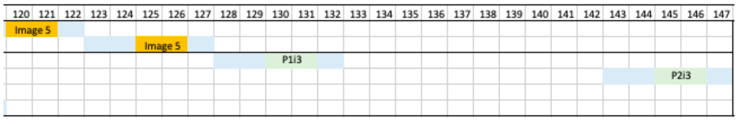
Models 9 and 10 include optimization of stacked HIDA scans with other nuclear medicine imaging studies.

Model 9: 2 HIDA scans with 2 Gastric Emptying studies. Image time indicated in first row, with HIDA image acquisition times highlighted in yellow, Gastric Emptying studies highlighted in Green, and transition time highlighted in blue. Each row indicates a single patient (1 scan). P indicates Patient, with i referring to Image number (ex: P1i2 indicates Patient 1, Image 2).



Model 10: 2 HIDA scans, 2 Gastric Emptying studies, and 2 other 20-minute studies. Other unspecified 20-minute studies highlighted in pink.

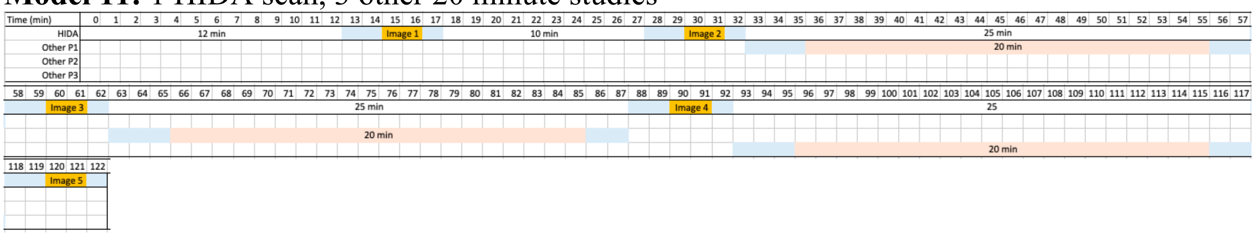




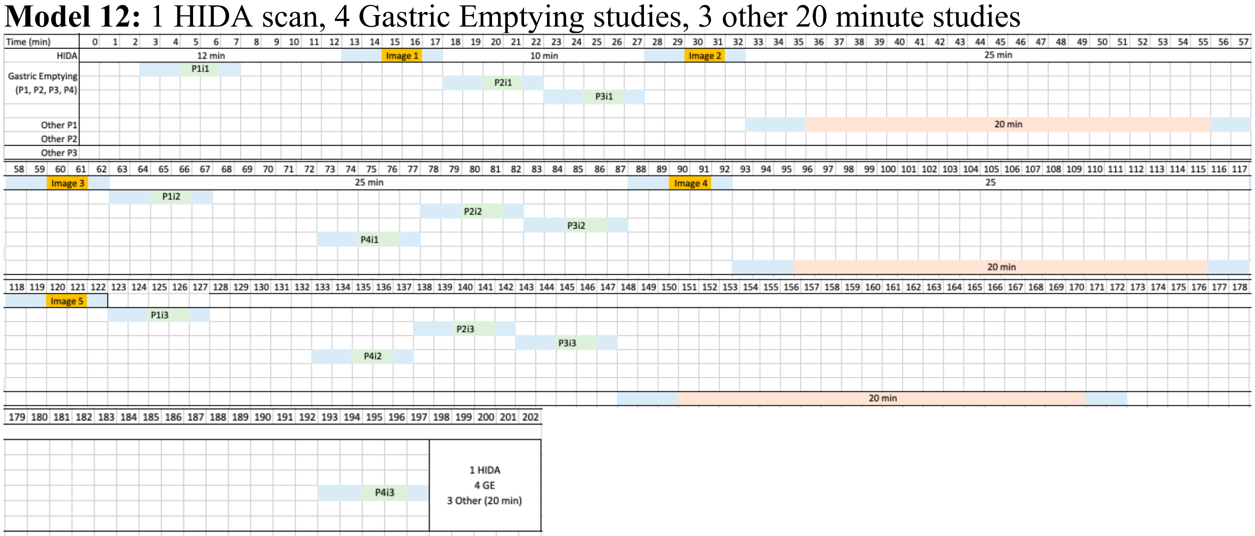
Of note, HIDA open scanner time in Model 10 allowed for only one minute of transition time between HIDA images 2 and 4 and the two 20-minute studies.

Models 11 and 12 show optimization of open scanner time within the novel HIDA protocol using other nuclear medicine studies. Model 11 shows optimization of the protocol with 20 minute blocks that could be utilized to run any 20 minute nuclear medicine study. Transition time in Model 11 ranged from 3 minutes for HIDA image 1, 5 minutes for HIDA image 5, 6 minutes between HIDA image 2 and other nuclear medicine study #1, to 8 minutes between HIDA images 3 and 4 and other nuclear medicine studies #2 and #3. Model 12 shows optimization using Gastric Emptying studies as well as 20 minute blocks for other nuclear medicine studies.

Model 11: 1 HIDA scan, 3 other 20 minute studies



Model 12: 1 HIDA scan, 4 Gastric Emptying studies, 3 other 20 minute studies



Stacked HIDAs

The data for stacked HIDA scan revenue are included in Table 2. As expected, minutes per cycle and revenue increased linearly with each additional scan. Total time of stacked cycles increased from 8.07 hours for one HIDA scan to 8.87 hours for the theoretical model including 7 stacked HIDA scans. Revenue generated by preforming more scans per day increased from a gross income per day of $2840.00 for the base model to a theoretical $19,880.00 per day. Gross income per year increased from $741,240.00 to a maximum theoretical gross per year of $5,188,680.00.

Table 2: Stacked HIDAs with Cycle Duration and Gross Revenue

Model #	HIDAs/Cycle	Cycle Duration (min)	Total Time (hrs)	Gross Per Cycle	Gross Per Day	Gross Per Year (261 work days)
BASE	1	121	8.07	$710.00	$2,840.00	$741,240.00
7	2	129	8.60	$1,420.00	$5,680.00	$1,482,480.00
8	2	130	8.67	$1,420.00	$5,680.00	$1,482,480.00
5	3	130	8.67	$2,130.00	$8,520.00	$2,223,720.00
6	3	132	8.80	$2,130.00	$8,520.00	$2,223,720.00
4	4	130	8.67	$2,840.00	$11,360.00	$2,964,960.00
3	5	133	8.87	$3,550.00	$14,200.00	$3,706,200.00
2	6	131	8.73	$4,260.00	$17,040.00	$4,447,440.00
1	7	133	8.87	$4,970.00	$19,880.00	$5,188,680.00

HIDAs with Other Studies

The data for HIDA scans with the addition of other imaging studies are included in Table 3. In these models, total time ranged from 6.57 hours per day to 8.13 hours per day. This equated to 1.5 hours less than one HIDA scan to seven minutes more than one HIDA scan using the current protocol. Minutes per cycle ranged from 122 to 197, allowing for 2-4 cycles to be run per 9-hour day. Revenue generated was the least in Model 9, which included 2 HIDA scans and 2 GE studies for a total duration of 7.35 hours. This model included the same number of scans as Model 11, however Model 11 required a total duration of 8.13 hours. Model 11 had fewer minutes per cycle at 122 vs. 147 minutes per cycle in Model 9, allowing adequate time for an extra cycle per 9-hour day. This resulted in an increased revenue from the base model of $1.61 million per year. Model 12 had the fewest number of cycles per day and was the second largest revenue generator, with a total of 8 scans per cycle. This model also had the shortest total time at 6.57 hours. Model 11 had the longest total time at 8.13 hours, and was the second highest revenue generator, at a Gross Income per year estimated to be around $2.35 million. The highest revenue generator was Model 10 at an estimated Gross Income per year of $2.69 million, with a total of 4 scans per cycle and running 3 cycles per day.

Table 3: Stacked HIDAs with Other studies

Model #	Scans	Minutes per Cycle	# of cycles per day	Total Time (hrs)	Gross Per Cycle	Gross Per Day	Gross Per Year (261 work days)
9	2 HIDA + 2 GEs	147	3	7.35	$2,412.00	$7,236.00	$1,888,596.00
10	2 HIDA + 2 GEs + 2 BS	147	3	7.35	$3,440.00	$10,320.00	$2,693,520.00
11	1 HIDA + 3 BS	122	4	8.13	$2,252.00	$9,008.00	$2,351,088.00

12	1 HIDA + 4 GEs + 3 BS	197	2	6.57	$4,236.00	$8,472.00	$2,211,192.00

DISCUSSION

The current study optimized the new imaging technique of hepatobiliary scintigraphy outlined by Verma et al. Using the new protocol, we were able to create multiple imaging models that involved stacking HIDA scans to allow for multiple scans to run simultaneously.

Optimization of scanner utilization is a delicate balance between maximizing scans per day and allowing sufficient transition time between images. It is expected that the process of positioning the patient on the scanner would require more time than allowing the patient to exit the scanner. We found that stacking HIDA scans with two minutes of transition time onto the scanner and one minute of transition time off of the scanner could be accomplished in 8.8 hours a day, with the addition of only 26 minutes per day to the initial imaging time for one HIDA scan. This would equate to an additional $1.48 million per year from the base HIDA scan model.

However, transition time will vary between imaging centers based on staffing capabilities, patient population, and facility design. This could be a significant limitation in settings that provide a majority of their services to older and less mobile patients who may have difficulty transferring onto or off of the imaging machinery. As a result, optimization of transition time, and therefore the choice of model for HIDA scan optimization, will be facility specific.

Reducing transition time permits very little error in patient positioning, which may result in an increase in medical imaging error. Successful image acquisition would rely on strict adherence to the model schedule to allow maximum transition time. Any adverse event could derail the schedule for the day, causing a negative experience for patients and a substantial loss of valuable imaging time for the facility. In addition to daily forfeitures, a mishap in a single daily schedule could affect scheduling many days in advance, as rescheduling incomplete or cancelled scans would result in a backup of the entire system.

Revenue may also be limited by staffing restrictions. The cost of hiring additional staff and/or providing supplementary training for staff to facilitate easy transition between image acquisitions, as well as to allow for consistent imaging throughout the 9-hour day, would need to be factored into overall revenue calculations.

These factors also highlight the importance of customizing each protocol to fit the needs and accommodations of the imaging facility. This may be accomplished by considering multiple models of scan cycles, including both stacked and combined variations. Stacking two HIDA scans with two Gastric Emptying (GE) studies would result in an increased gross yearly revenue of $1.15 million from the base model, with a total imaging time of 7.35 hours per day. This is less time than the established HIDA scan total time, which requires 8.07 hours for four scan cycles. Additionally, the stacked HIDA with GE studies model only required three cycles, which would allow more flexibility for the imaging facility.

Running one HIDA with 3 Bone Scans would result in a gross revenue of $2.35 million, which is a difference of $1.61 million from the base model. This model required 8.13 hours to complete, making it the longest of the combined imaging study models. However, time per day of this model was 0.67 hours less and generated $127,368 more per year than stacking HIDA scans alone. Incorporation of other nuclear medicine scans into the new HIDA protocol is likely more realistic than stacking HIDA scans only, and is in fact more lucrative.

One HIDA scan stacked with 4 GEs and 3 Bone Scans could be accomplished in 6.75 hours per day, which would accommodate two scan cycles and result in a gross revenue of approximately $2.21 million - an increase of $1.47 million from the base model. This model showed the greatest flexibility and could therefore be beneficial in settings with lower HIDA scan volume and those that benefit more significantly from careful use of HIDA open scanner time.

A limitation of this study is the use of extrapolation to arrive at gross income values. The data presented in this study are based on imaging cost values from Medicare codes, which may vary in reimbursement significantly. Gross revenue figures may look drastically different for practices with high Medicare patient populations. Additionally, these values are based on hypothetical models that may or may not be feasible or applicable to a given practice setting. The relationship between reimbursement and imaging utilization may not be linear; however, the trend of the data remains true regardless of specific imaging procedure costs.

The current study provides multiple customizable models using a novel hepatobiliary scintigraphy protocol to enhance imaging center workflow and revenue. Thoughtful and intentional optimization of open scanner time by use of these models could result in appreciably enhanced efficiency to offset cost, reduce downtime, and increase patient satisfaction.

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