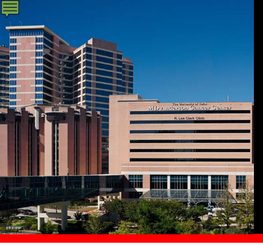

Creation and implementation of a standardized work for CT-guided biopsy procedures

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Overview

This work was a team effort and represents the collaborative efforts of a core group of medical physicists, interventional radiologists, and technologists to improve the practice of computed tomography (CT)-guided biopsy procedures in the interventional radiology department at The University of Texas MD Anderson Cancer Center.

At our institution, CT-guided biopsies were performed without standardization. Technical factors such as kVp and mAs for diagnostic CT exams are carefully tailored to individual patients based on their size, however, in many institutions this approach is not applied for CT-guided interventional procedures. Adapting techniques to individual patients and standardizing the procedure is expected to reduce overall radiation dose and reduce variability in image quality.

These efforts are also closely aligned with the Joint Commission Sentinel Event Alert 47 [1], published in August 2011, which highlights the importance of this project. This alert addressed radiation risks in diagnostic imaging, and amongst other suggested actions, recommended using the "Right dose", "Effective processes", and establishing a "Safety culture" to protect patients undergoing imaging procedures.

Aim statement

Our goal was to standardize the performance of CT-guided biopsy procedures in interventional radiology by creating and implementing a 5-step standardized work.

Measures of success

We measured the impact of standardization on overall dose and image quality, while at the same time measuring the impact on factors we did not wish to affect, including procedure time, complication rate, and rate of diagnostic yield. CT metrics including the volume computed tomography dose index ($CTDI_{vol}$) and dose-length product (DLP) were used to quantify dose. Image quality was assessed by measuring the coefficient of variation (CoV) in image noise between the pre-study and study periods.

We used Fisher's exact test to evaluate categorical data, and tested differences in means in the pre-study and study periods using two independent sample *t*-tests. Differences in variation were measured using a folded F-test.

Use of quality tools

We created a **standardized work** to document and outline the best practice for performing CT-guided biopsy procedures. Based on our experience, we knew that the procedural planning scan (PPS) length could be restricted to the area of interest based on prior cross-sectional imaging. We were also aware that in our current practice CT techniques were either not adapted to patient size, or adjusted randomly. This was in contrast to best practice for diagnostic CT at our institution and other institutions [2,3]. Based on this knowledge, we created our standardized work (Fig. 1, lower right corner).

Interventions

Our improvement plan was implemented as follows:

1. A standardized work for performing CT-guided biopsy procedures was created. Medical physicists, interventional radiologists, and technologist supervisors collaborated to create the standardized work.
2. The standardized work was introduced to technologists and interventional radiologists. Technologists were trained in the use of the standardized work by AT (interventional radiologist) and KH (technologist supervisor).
3. The impact of the standardized work was evaluated after a three month study period by AT and AKJ (medical physicist).
4. Adjustments to our practice and the standardized work were made based on our findings to further drive improvement. Results were communicated to technologists by KH during a monthly staff meeting, highlighting both good performance and areas targeted for continued improvement; results were communicated to radiologists by AT at the monthly faculty meeting.

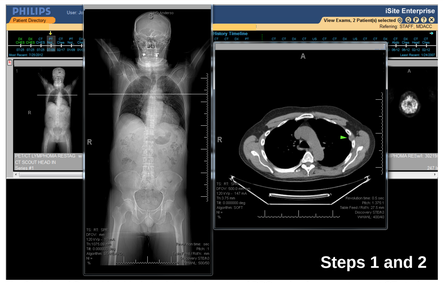

Fig. 2a. Use of Scout Line Mode to determine center of PPS region from most recent CT study.

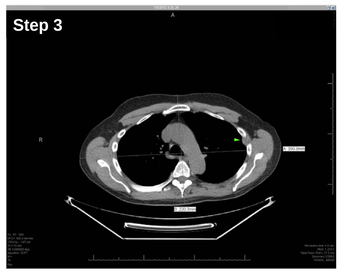

Fig. 2b. Measurement of AP and transverse patient dimensions at the level of the lesion to be biopsied (arrow). Sum of AP + Trans dimensions is 22 cm + 40 cm = 62 cm.

LUNG

AP + Trans dimension	mAs	AP + Trans dimension	mAs
32	17	62	44
33	17	63	47
34	17	64	50
35	17	65	53
36	17	66	57
37	17	67	61
38	17	68	65
39	17	69	69
40	17	70	74
41	17	71	79
42	17	72	84
43	17	73	90
44	17	74	96
45	17	75	102
46	17	76	109
47	17	77	117
48	18	78	124
49	19	79	133
50	20	80	142
51	21	81	151
52	23	82	162
53	24	83	172
54	26	84	184
55	28	85	196
56	30	86	210
57	32	87	224
58	34	88	239
59	36	89	255
60	39	90	272
61	41		

Fig. 2c. For dimensions of 62 cm, the technical factors for this biopsy should be **120 kVp, 44 mAs**.

Step 4

Fig. 2d. PPS range and technical factors set according to standardized work.

Step 5

Results

A total of 1,165 biopsy procedures were analyzed between the pre-study and study periods. Overall, the total DLP decreased by 71.9% (689 mGy-cm pre-study versus 193.9 mGy-cm study, $P < 0.0001$) after implementation of the standardized work. Significant decreases in DLP were also observed when the results were stratified by biopsy site (Table 1).

Tissue was sampled successfully in all biopsy procedures, and there was no difference in patient age, body mass index (BMI), complication rate, rate of diagnostic yield, and procedure time between the pre-study and study periods.

The decrease in DLP was driven by both a reduction in the mean length of the PPS (198.8 mm pre-study versus 125.1 mm study, $P < 0.0001$), addressed by Step 5 in the standardized work, and a decrease in the mean $CTDI_{vol}$/5 mm* (1.7 mGy pre-study versus 0.72 mGy study, $P < 0.0001$), addressed by Step 4 in the standardized work. $CTDI_{vol}$/5 mm decreased regardless of BMI, however, percentage decreases were less for larger patients, as expected (Table 2). Inter-physician variability in patient doses decreased between the pre-study and study periods (Fig. 3).

The coefficient of variation (CoV) of image noise decreased from 0.40 during the pre-study period to 0.32 during the study period ($P < 0.0001$), demonstrating increased standardization of image quality (Table 3). Overall, noise increased in the study period (Table 3) but images were still adequate for performing CT-guided biopsy (Fig. 4)

Changes were made to our standardized work in response to our results, including re-educating technologists about anatomical landmarks and adding a table to the standardized work for solid organ biopsies (Fig. 1, lower right corner). Solid organ was the site with the most deviations from the standardized work during the study period, owing to physician requests for increased mAs.

*$CTDI_{vol}$/5 mm was defined as the total $CTDI_{vol}$ for the biopsy scans normalized to 5 mm of scan coverage

Generalizability

Our standardized work is easily generalizable and we have already entertained requests for assistance in implementing our standardized work at other institutions in the Texas Medical Center. Technique charts can be adapted for any make and model of CT scanner used to perform CT-guided biopsies, and for any baseline image quality desired by physicians.

Conclusion and next steps

The creation and implementation of a standardized work for performing CT-guided biopsy procedures resulted in a significant decrease in overall patient radiation dose, reduced procedural variability, and standardized image quality. We continue to improve our standardized work by evaluating new data every three months and making necessary adjustments.

References

1. The Joint Commission. Sentinel Event Alert 47, available at http://www.jointcommission.org/assets/1/18/SEA_47.pdf, accessed 9/2012, 2011.
2. Frush DP, Soden B, Frush KS, Lowry C. Improved pediatric multidetector body CT using a size-based color-coded format, Am J Roentgenol 178:721-26, 2002.
3. Joint Task Force on Adult Radiation Protection. Image Wisely Campaign, available at www.imagewisely.org, accessed 9/2012.

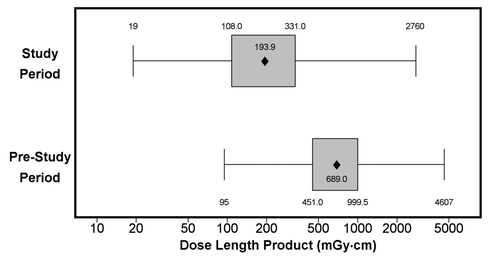

Fig. 3. Reductions in both mean DLP (diamonds) and inter-quartile range were observed after implementation of the standardized work.

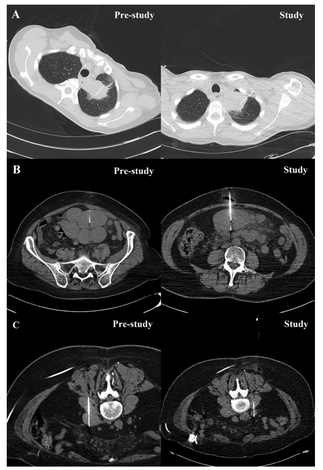

Fig. 4. Biopsy images from patients who underwent CT-guided biopsy in both the pre-study and study periods. The study period images demonstrate an increase in image noise but the biopsy needle, target lesion and adjacent structures were clearly visualized. (A) Patient, BMI 19.9, with non-small cell lung cancer of the left upper lobe. The DLP was 489 mGy-cm in the pre-study period versus 69 mGy-cm in the study period. (B) Patient, BMI 24.6, with a history of lymphoma and a mesenteric mass. The DLP was 758 mGy-cm in the pre-study period versus 104 mGy-cm in the study period. (C) Patient, BMI 34.9, with a history of lymphoma and bilateral retroperitoneal lymphadenopathy. The DLP was 636 mGy-cm in the pre-study period for biopsy of the 3 cm right retroperitoneal lymph node versus 173 mGy-cm in the study period for biopsy of the 1 cm left para-aortic lymph node.

Table 1. Comparison of dose-length product (DLP) before and after implementation of standardized work.

	Period					
	Pre-study		Study			
Biopsy site	N	Geometric mean	N	Geometric mean	Reduction in DLP (%)	*P*-value
Lung	265	757.3	248	150.8	80.1	< 0.0001
Solid organ*	78	735.7	42	304.0	58.7	< 0.0001
Lymph node	192	659.2	182	260.2	60.5	< 0.0001
Bone	77	520.0	81	171.4	67.0	< 0.0001
All	612	689.0	553	193.9	71.9	< 0.0001

*The solid organ biopsy category includes liver, kidney, adrenal and spleen biopsies.

Table 2. Comparison of $CTDI_{vol}$/5 mm* before and after implementation of the standardized work.

	Period					
	Pre-Study		Study			
BMI category†	N	Mean	N	Mean	Reduction (%)	*P*-value
BMI < 25	218	1.40	183	0.486	65.2	< 0.0001
25 ≤ BMI < 30	196	1.71	200	0.681	60.2	< 0.0001
30 ≤ BMI < 35	98	1.74	87	1.04	40.6	< 0.0001
BMI ≥ 35	101	2.18	75	1.42	34.9	< 0.0001

*$CTDI_{vol}$/5 mm was defined as the total $CTDI_{vol}$ for the biopsy scans normalized to 5 mm of scan coverage
†BMI categories were adapted from the modified WHO criteria for classification of obesity. (http://apps.who.int/bmi/index.jsp?introPage=intro_3.html, accessed 10/31/2012)

Table 3. Comparison of image quality before and after implementation of standardized work.

	Period							
	Pre-study			Study			*P*-value	
Biopsy site	N	Normalized image noise*	CoV†	N	Normalized image noise*	CoV†	Mean	CoV†
Lung	265	11.9	0.365	234	18.9	0.355	< 0.0001	0.6708
Solid organ	78	14.4	0.298	30	21.1	0.231	< 0.0001	0.1421
Lymph node	192	14.6	0.420	138	20.2	0.269	< 0.0001	< 0.0001
Bone	77	13.9	0.463	67	19.5	0.323	< 0.0001	0.0059
All	612	13.3	0.400	469	19.5	0.321	< 0.0001	< 0.0001

*Geometric mean. Note: Higher values indicate higher noise levels in biopsy images.
†Coefficient of variation (CoV) of image noise.

CT IR 3

CHEST

AP + Trans dimension	mAs	AP + Trans dimension	mAs
32	17	62	44
33	17	63	47
34	17	64	50
35	17	65	53
36	17	66	57
37	17	67	61
38	17	68	65
39	17	69	69
40	17	70	74
41	17	71	79
42	17	72	84
43	17	73	90
44	17	74	96
45	17	75	102
46	17	76	109
47	17	77	117
48	18	78	124
49	19	79	133
50	20	80	142
51	21	81	151
52	23	82	162
53	24	83	172
54	26	84	184
55	28	85	196
56	30	86	210
57	32	87	224
58	34	88	239
59	36	89	255
60	39	90	272
61	41		

ABDOMEN/PELVIS

AP + Trans dimension	mAs	AP + Trans dimension	mAs
32	17	62	82
33	17	63	90
34	17	64	100
35	17	65	111
36	17	66	123
37	17	67	136
38	17	68	150
39	17	69	166
40	17	70	184
41	17	71	204
42	17	72	225
43	17	73	249
44	17	74	276
45	17	75	306
46	17	76	338
47	18	77	374
48	20	78	414
49	22	79	459
50	24	80	508
51	27	81	562
52	30	**82**	**415**
53	33	**83**	**459**
54	36	**84**	**492**
55	40	**85**	**492**
56	44	**86**	**492**
57	49	**87**	**492**
58	54	**88**	**492**
59	60	**89**	**492**
60	67	**90**	**492**
61	74		

*Note: For table entries in **bold** use **140 kV**.

SOLID ORGAN

AP + Trans dimension	mAs	AP + Trans dimension	mAs
32	17	62	122
33	17	63	136
34	17	64	150
35	17	65	166
36	17	66	184
37	17	67	203
38	17	68	225
39	17	69	249
40	17	70	276
41	17	71	305
42	17	72	338
43	18	73	374
44	20	74	414
45	22	75	458
46	24	76	507
47	27	77	562
48	30	**78**	**414**
49	33	**79**	**459**
50	36	**80**	**492**
51	40	**81**	**492**
52	44	**82**	**492**
53	49	**83**	**492**
54	54	**84**	**492**
55	60	**85**	**492**
56	67	**86**	**492**
57	74	**87**	**492**
58	82	**88**	**492**
59	90	**89**	**492**
60	100	**90**	**492**
61	111		

*Note: For table entries in **bold** use **140 kV**.

Checklist for CT-guided Biopsy

1. In the EMR, locate target lesion on the referenced diagnostic cross-sectional imaging study.
2. Use scout line mode to determine anatomic landmark.
3. Sum the AP and transverse dimensions on the reference image. If the full transverse extent is not visualized on the cross-sectional image, measure the transverse dimension using the topogram.
4. Use sum of AP and transverse dimensions to determine the appropriate kVp and mAs from chart for preplan and biopsy modes. Any rotation time can be used.
5. Set the length of the preplan scan to **75 mm** and center the range on the landmark.
6. Scan

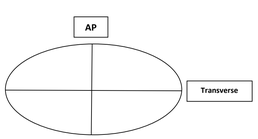

Fig. 1 Standardized work used to determine CT biopsy techniques. Modifications include: Added separate chart for SOLID ORGAN (highlighted) with higher baseline mA, charts identified by body region, prescan length bolded.