Procedure Complexity and Utilization Distributions for Interventional CT

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Presentation outline

- Background/Motivation
- Procedure Complexity
- · Previous Studies on Interventional CT Dose Survey

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· MGH Study

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Background/Motivation

Interventional CT has very different characteristics from diagnostic CT:

- · Relatively lower image quality
- Many repeated short scans
- Strong metal artifact
- · Procedure/Site specific
- The related CT dose/image quality has not been thoroughly studied.



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Background/Motivation

- · The operator determines the progress of the procedure
- High potential to utilize much higher radiation dose than diagnostic CT scans
- For a single procedure, the total effective dose could go above 100 mSv*.

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*Leng S, Christner JA, Carlson SK, et al. Radiation dose levels for interventional CT procedures. AJR Am J Roentgenol 2011;197(1):W97–W103

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Background/Motivation

- It is critical to understand all the related clinical procedures for CTGI.
- It will be ideal to have a quantitative parameter to measure the necessary dose range or reference level.

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· Biggest challenge is the procedure complexity.

How to quantify procedure complexity



Example from Fluoroscopy

COMPLEXITY INDEX FOR PERCUTANEOUS TRANSLUMINAL CORONARY ANGIOPLASTY PROCEDURES

CORONARY ANGOPLAST PROCEDURES This workness functionality, biveness the complexity factors of a PTCA proceeding and the observed technical factors such as FT mumber of cine frames and terms arear product (*T_C*). Multiple finance regressions produced a C capable of predicting the level of patient repressi-tis index provides a tool for comparing individual practices and institutions well as permitting a neumalized comparison with judiance levels. Samples of PTCA procedings were coelcleck from canadiac centre located in Chile, Taby, Spain and Urganya. The mean patient age at all centres ranged between 61 and 65 years (danatad utdaviations between 8 and 12 years). dosimetric data are summarized in Table 21. Each centre's sample was initially decided to verify that consistency and to make a subjective caluation of the complexity mix at that centre. Relevant clinical data are summarized in Table 23. we transmit

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Complex Index for PTCA

All PTCA (857 cases)	Multi- vessel	Lesion	Occlusion > 3 months	Severe	Ostial stenting	Bifurcation
Number of cases	117	161	24	25	22	58
Coefficients (min) (p value, 2 tail)	9.75 (0.000)	4.98 (0.000)	7.20 (0.002)	6.77 (0.000)		5.66 (0.000)
Weighting factors for the complexity index	1	0.51	0.73	0.69		0.58

and the den	ed weighting	factors reporte	al in Table 25.	All factors	have a j
(2 tail) < 0.9					
The de	ived weighting	Eactors were a	profied to each	PTCA case	to derive
the substitut i	1				

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Naver * 1 + No.LesType * 0.51 + No. + No.SerTort * 0.69 + No.BifSt * 0.58 dian values of the CI for each of the six sex were reported from Spain B and other centres, red CI, the whole sample was divided into three

le' PTCA procedures with CI = 1; im complex' PTCA procedures with I < CI < 2; ilex' PTCA procedures with CI > 2. Segmentation of the procedures into three complexity groups was ted using r tests. FT, total P_{KA} and fluoroscopic P_{KA} were compared on groups. All two-tail p values were < 0.001. 10

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CI more than patient size



FIG. 26. L. trend line.

TABLE 28. REFERENCE (GUIDANCE) LEVELS FOR SIMPLE, MEDIUM AND COMPLEX PERCUTANEOUS TRANSLUMINAL CORONARY ANGIOPLASTY PROCEDURES EXPRESSED IN TERMS OF FLUOROSCOPY TIME AND $P_{\rm KA}$

	Reference	e (guidance) levels	
Complexity group	Fluoroscopy time (min)	Number of images	P _{KA} (%)
Simple CI = 1	15	1500	100
Medium 1 < CI <= 2	20	1650	130
Complex CI > 2	32	2250	200

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Higher complexity, more imaging utilization, higher dose -9-





Key Factors

- · Procedure types Complexity/Utilization
- Operator experience
- Patient size/condition
- · Institutional practice
 - Scanner models
 - Scanning modes Helical, Axial, Mix

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Utilizing available data from CT dose monitoring

Dose Metric

- CT scan parameters as surrogates?
 - CTDIvol
 - SSDE
 - DLP
 - Total scan length
 - Number of images Utilization Metric

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- Number of acquisitions

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Dose Survey Studies - Tsalafoutas, 2007

CT-Guided Interventional Procedures without CT Fluoroscopy Assistance: Patient Effective Dose and Absorbed Dose Considerations

loannis A. Tsalafoutas^{1,2} Virginia Tsapaki¹ Charicleia Triantopoulou¹ Akrivi Gorantonaki¹ John Papailiou¹ OBJECTIVE. The purpose of this study was to determine patient effective dose (*k*) and peak absorbed dose to the skin of the patient from various CT-patiend interventional precedence performed without CT fromeworp solutions. Constructions were not respectively studied. 14 hospits, 14 ndiofrequency abations, 14 abaccs drainages, and seven neprotectively studied. 14 hospits, 14 ndiofrequency abations, 14 abaccs drainages, and seven neprotectively studied mages were acquired from the depatterned PACS system and previous for texture to scan perrameters of each skice. Entrance surface dose and *E* were estimated using the Impaction data base and the related block Carlor corresponse coefficients.

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Dose Survey Studies - Tsalafoutas, 2007

	Patient	Canadar ^a			Peak			
Procedure	AP (cm)	Lataral (cn)	le. et Siess	Dverlag	Dose (mGy)	DLP (mDy cm)	(E) (nSi)	Tree (1)
lapsies				(H patients: 7)	nale, 7 femalo)			
Range	17-32	25-29	45-198	3-57	123-982	454-201	58-466	\$13-2.5
Nedan	22.5	33.3	130	13	281	1334	23.0	0.36
Mean ± \$D	24±5	33 ± 4	121 = 48	15 : 7	348 = 220	1418 ± 591	25 z 11	0.29 ± 0.1
adiafrequency ablations		-		(H patients: 10	mais, 4 female)			
Rango	25-34	28-35	84-208	3-30	147-439	194-3222	18.4-57.2	136-22
Nedan	25	33.5	172	28	557	1971	35.3	1/9
Mean ± SD	28 ± 3	32±3	167 ± 50	20::7	494 ± 187	1876 ± 666	35 ± 12	1/22 ± 82
Bacess drainages				(H patients: 8)	nale, 6 famale)			
Range	28-31	25-40	58-146	5-15	94-315	548-1345	169-315	105-11
Median	25.3	33.9	83		195	843	16.2	0.61
Mean x SD	25 : 3	35 : 4	90 x 30	5:3	175 : 66	1983 x 471	1816	243:21
Vephrostomies				(7 patients: 2 m	ale, Stimale)			
Rungo	25-28	29-38	37-548	4-15	75-297	440-1990	\$1-327	121-15
Nedan	21	31.5	58		145	710	11.5	051
Mean ± SD	72 ± 3	33:3	71:35	8:5	173 ± 86	879 : 472	15±9	249:27

	Stage							
Procedure and Dose	A	B	C	D	E	F		
Biopsies								
Absorbed	0.9	17.3	144	11.2	47	85		
Effective	2.2	63.0	2.4	2.8	15.4	13		
Radiofrequency ablations								
Absorbed	0.5	7.2	11.1	11.3	56.5	85		
Effective	1.7	32.6	6.0	35	29.8	27.5		
Drainages								
Absorbed	1.8	15.1	16.3	11.1	40.5	12.8		
Effective	2.4	40.3	48	1.4	18.8	19		
Nephrostamy								
Absorbed	2.9	13.2	\$3	16.6	485	81		
Effective	49	51.2	7.5	36	24.4	15.3		

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Dose Survey Studies – Leng, et al 2010

Radiation Dose Levels for Interventional CT Procedures

Shuai Leng¹ Jodie A. Christner Stephanie K. Carlson Megan Jacobsen Thomas J. Vrieze Thomas D. Atwell Cynthia H. McCollough OBJECTIVE. The purpose of this study was to determine typical radiation dose levels to patients undergoing CT guided interventional proceedures. MATERIALS AND METHODS. At total of 371 patients sundergoing CT interventional procedures were included in this retrospective data analysis study. Earnolded patients and the study of the each procedure, two stars mades were used, table intermediate to the list intervention of the list data and the study of the study of the study of the study of the study and plantom measurements. Fifteetice does was a calculated by multiplying doe-length product (DLP) and conversion factor (L facet) for helical mode, and using Monte Carlo organ dose coefficients for interminition mode.

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Dose Survey Studies – Kloeckner, et al 2013



Dose Survey Studies – I	Kloeckner,et al 2013
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Intervention type	п	DLP peri-	interv.CT serie	es(mGycm)	DLP CTF (mGy cm)			Total DLP (mGy cm)			P
		Mean	Median	Q3	Mean	Median	Q3	Mean	Median	Q3	
Abdominal drainage	335	694	636	830	108	43	98	802	719	942	<0.00
Pleural drainage	117	490	483	566	45	23	48	535	521	630	<0.00
Liver biopsy	406	712	652	804	136	68	159	848	760	982	<0.00
Lung/pleura biopsy	242	507	481	553	91	35	97	598	538	662	<0.00
Retroperitoneal biopsys	115	781	723	946	108	34	123	889	781	1098	<0.00
Mediastinal biopsy	34	549	468	649	175	89	164	724	595	891	<0.00
Renal/suprarenal biopsy	29	703	679	835	66	34	72	769	738	899	<0.00
REA/MWA liver	85	1220	1127	1469	274	164	250	1495	1403	1906	<0.00
RFA/MWA bone	15	276	233	404	147	153	213	423	470	567	0.00
RFA/MWA lung	8	597	572	835	407	407	580	1004	932	1270	0.1
ain block	23	787	791	896	159	109	176	946	948	1174	<0.0
Vertebroplasty	167	1313	1284	1449	179	148	216	1493	1454	1666	<0.0

Diagnostic scan parameters were used for peri-interventional series

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Dose Survey Studies - Yang, et al 2018 This copy is for personal use only. To order printed copies, contact *reprints@rma.org* ORIGINAL RESEARCH • MEDICAL PHYSICS Procedure-specific CT Dose and Utilization Factors for CT-guided Interventional Procedures Kai Yang, PhD • Suurramu Ganguli, MD • Matthew C. DeLorenzo, MS • Hui Zbeng, PhD • Xinhua Li, PhD • Bob Lin, PhD

From the Division of Diagnoric Inaging (Payris), Deparament of Radioing (KX, M.C.D., XL, B.L.), and Center for Image Gaided Gancer Therapy, Deparament of Interventional Radioing (SGL), Montakanane General Houpida, ST Ama Ste, Bonne, MA (B114, and MGH Binearistica Gener, Room, Man (B L2), Bortend De-tractional II, 307) without sequence of the space of th See also the collocal by Long or one save. Radiology 2018, 289:150–157 • https://doi.org/10.1148/radiol.2018172945 • Content code CT

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Dose Survey Studies - Tsapaki, et al 2019



Dose Survey Studies - Tsapaki, et al 2019

	Curren	at study	Tsalafo	utas 2007		Klotck	ner 2013*	Yang	g 2018
CT procedure	N	DLP	N	DLP	N	DLP	Preliminary DRLs	N	DLP
Biopsy	31	975	14	1334	826	692	982	4425	1175
Drainage	45	793	14	840	452	648	942	2365	1125
Ablation	12	1377	14	1971	85	1403	1906	679	2351
		954							
Nephrostomy CT fluoroscopy tech	nique	Ta	ble 6. T ainage,	ypical DF ablation	Ls in to and ne	erms of phrost	DLP for biopsy	•	
Nephrostomy CT fluoroscopy tech	nique	Ta	ble 6. T ainage,	ypical DF ablation	Ls in to and ne	erms of phrost	DLP for biopsy	•	
Nephrostomy T fluoroscopy tech	nique	Tadr	ble 6. T ainage,	ypical DF ablation	Ls in t and ne	erms of phrosto Typic I	DLP for biopsy omy ral DRLs DLP	•	
Nephrostomy T fluoroscopy tech	nițue	Ta dr CI Bi	ble 6. T ainage, proced	ypical DF ablation	Ls in to and ne	erms of phrosto <i>Typic</i> I	DLP for biopsy omy al DRLs DLP 080	•	
Nephrostomy CT fluoroscopy tech	nique	Ta dr CI Bio Dr	ble 6. T ainage, proced opsy ainage	ypical DF ablation	Ls in t	erms of phrosto Typic I	DLP for biopsy omy al DRLs DLP 280 790		
Nephrostomy	15 nățue	Ta dr CI Bio Dr	ble 6. T ainage, proced opsy ainage clation	ypical DR ablation	Ls in to and no	erms of phrosto Typic I	DLP for blopsy omy cal DRLs DLP 280 290 380		



MGH Study

- To perform detailed analysis of interventional CT dose distribution at MGH.
- To explore the possibility to derive a quantitative metric to assess procedural complexity and CT utilization using CT dose metric as a surrogate.

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Methods - Overview

- · IRB approved retrospective study.
- Dictation reports collected for CT guided interventional cases performed at MGH from 2012 to 2017.
- CT dose data extracted using Radimetrics platform (Bayer HealthCare, Whippany, NJ).
- Four major categories and twenty-one sub-categories were created.

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Methods – Intervention Category

(AB) Ablation	(AS) Aspiration	(B) Biopsy Fiducial marker	(D & DC) Drainage Tube placement
AB1 idney/Adrenal	AS1 Abdomen	81 Lung Mediastinum	Abdomen (D)
AB2 Bone/Marrow AB3	AS2 Chest	B2 Renal/Adrenal B3 Bone B4 Soft tissue	(s1,s2,x3+)
Soft tissue Lymph node	AS3 Joint/Bone/	B5 Liver/Galibladder	
AB4 Liver AB5 Lung	AS4 Celiac plexus block	85 Spiedin/Pancreas 87 Retroperitoneum/ Mesenteric	Chest (DC) (x1,x2)

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campery .	T'serren and a series of the s	(a), or storedung
Wation		679
AB1	Renal/adrenal ablation	187
AB2	Borse ablation	43
AB3	Soft tissue ablation	28
AB4	Liver ablation	394
AB5	Lung ablation	27
opinition.		744
AS1	Abdominal argination	145
A52	Chert aspiration	282
AS3	Bone aspiration/injection	257
A\$4	Celuc plenus block	60
kepsy		4425
81	Lung biopsy	884
82	Renal/adrenal biopsy	547
83	Bone biopsy	760
84	Soft tissue biopsy	253
85	Liver biopsy	-997
B6	Pancrear biopsy	- 25
87	Repreparioneal/mesonatic biopsy	959
Insinage		2365
DI	Abdominal drainage, I drain	1571
D2	Abdominal drainage, 2 drains	279
D3	Abdominal drainage, 3 or more draino	127
DCI	Chest drainage, 1 drain.	354
DC1	Chest drainage, 2 drains	. 34

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Methods - CT Dose Data

- CTDIvol (mGy): Volume CT Dose index
- DLP (mGycm): Dose-Length-Product
- SSDE (mGy)
- Scan Length (mm)
- Acquisition Count
- · Number of Images

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Results – Acquisition Count











Utilization Factor by	$scan length(SL) = \frac{SL subcategory median}{SL global median}$	
Utilization Factor by acq	$uisition \ count(AC) = \frac{AC \ subcategory \ median}{AC \ global \ median},$	
Utilization Factor by nu	mber of images(NI) = $\frac{NI \text{ subcategory median}}{NI \text{ global median}}$,	
erall Utilization Factor = Utilizat	tion Factor by SL + Utilization Factor by AC + Uti 3	ilization Factor by NI





Discussion

- · Single institute study
- Only helical scan CT included (did not include CT fluoroscopy or ultrasound assisted procedures)
- DLP and CTDIvol slightly depends on patient size, which has a relatively small variation for this population
- · Large variations between different procedures
- The complexity/utilization factors might be applicable to institutes using CT fluoroscopy

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Summary

With a large number of cases analyzed and detailed categorization of CT guided interventional procedures (CTGI), consistent and procedure-specific dose metric distributions are presented and quantitative complexity/utilization factors for CTGI procedures are provided.

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Future

- Robot/Al
- · Different requirement for image quality
- · More accurate/efficient procedure

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Future

Radiology

Ultra–Low Radiation Dose CT Fluoroscopy for Percutaneous Interventions: A Porcine Feasibility Study

Metrin G. Wingner, Dr. e. Isani * J. Lanis Handani, MD. • Yandong LJ, PhD. • Tanody P. Scoplastanica, PhD. • Paul Landon, MD, PhD. • Charlos, A. Manetta, PhD. • (Paul T. Lei, J. MD. Then the Dynamic Michigani, Phys. Rev. F. 1997, C. M. Babley (2)L. FTF, H. C. M. (TLL), Using (2)L. FTJ, 1 and Wanoklas Taymeng (2)L. FTL, Userson (49)Winsten Maina, 111 Hightad Acadama, W150W. Intend 400, 7, 2018, revises squared by 18, notion mined Outer 10, starsp. Nature Michigan, MD (2018, 2018), Starspeet and Michigan W150W. Starspeet and the Stars

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Conflicts of interest are listed at the end of this article.

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CONTRACTORISTING

ORIGINAL RESEARCH • VASCULAR AND INTERVENTIONAL RADIOLOGY

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