

The VAMPIRE Challenge:  
Preliminary results from a multi-institutional study of  
CT ventilation image accuracy

SYDNEY MEDICAL SCHOOL

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UNIVERSITY OF SYDNEY



SAM JOINT IMAGING-THERAPY SCIENTIFIC SYMPOSIUM  
AAPM Annual Meeting, July 31<sup>st</sup> - August 4<sup>th</sup> 2016  
Washington DC, USA

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Learning Objectives

- ① To understand the need for common datasets to validate and improve CT ventilation imaging (CTVI)
- ② To learn about common tools for evaluating CTVI accuracy
- ③ To learn about a global initiative to identify the most accurate CTVI algorithms

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Outline

- › Goals and barriers for cross-modality validation of CTVI
- › VAMPIRE: Realizing a multi-institutional validation dataset for CTVI
- › VAMPIRE Challenge: Preliminary results based on USYD algorithm

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## Outline

- › **Goals and barriers for cross-modality validation of CTVI**
- › **VAMPIRE: Realizing a multi-institutional validation dataset for CTVI**
- › **VAMPIRE Challenge: Preliminary results based on USYD algorithm**

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## Goals and barriers for cross-modality validation

- **CTVI-guided functional avoidance lung cancer RT is now a clinical reality and can have a material impact on functional dosimetry.**

Contents lists available at [ScienceDirect](http://ScienceDirect)  
**Radiotherapy and Oncology**  
 Journal homepage: [www.thegreenjournal.com](http://www.thegreenjournal.com)

**Original article**  
**The first patient treatment of computed tomography ventilation functional image-guided radiotherapy for lung cancer**  
 Takahiro Yamamoto <sup>∗,†</sup>, Sven Kabus <sup>∗,†</sup>, Matthieu Bal <sup>∗</sup>, Paul Keall <sup>∗</sup>, Stanley Benedict <sup>∗</sup>, Megan Daly <sup>∗</sup>

<sup>∗</sup>Department of Radiation Therapy, University of Sydney, South Sydney, NSW, Australia; <sup>†</sup>Department of Digital Imaging, Physics Research, Westmead, Sydney, NSW, Australia; <sup>‡</sup>Centre for Particle Therapy, The University of Sydney, Sydney, NSW, Australia; <sup>§</sup>Department of Radiation Oncology, University of Sydney, Sydney, NSW, Australia

T. Yamamoto et al. (2016)  
 Radiother Oncol

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## Goals and barriers for cross-modality validation

- › **AAPM abstracts with "ventilation" in the title, many focusing on validation:**

50-10-200-4	Study and Development of a New High Precision Ventilation CT Quantitatively Evaluating CT Based Pulmonary Ventilation Imaging. J. Hwang <sup>1</sup> , J. Hwang <sup>1</sup> , J. Hwang <sup>1</sup> , J. Hwang <sup>1</sup> , J. Hwang <sup>1</sup> , J. Hwang <sup>1</sup> . <sup>1</sup> Department of Radiation Therapy, University of Sydney, Sydney, NSW, Australia; <sup>2</sup> Department of Physics, University of Sydney, Sydney, NSW, Australia.	50-10-200-5	Investigating Regional Ventilation Function in Pre-treatment CT for Lung Cancer. J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> . <sup>1</sup> Department of Radiation Therapy, University of Sydney, Sydney, NSW, Australia; <sup>2</sup> Department of Physics, University of Sydney, Sydney, NSW, Australia.
50-10-200-6	Role of Functional-CT-Function in Ventilation in MIP of NCICT. J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> . <sup>1</sup> Department of Radiation Therapy, University of Sydney, Sydney, NSW, Australia; <sup>2</sup> Department of Physics, University of Sydney, Sydney, NSW, Australia.	50-10-200-6	Quantifying the Relative Change Due to Radiation Therapy Using 4DCT Inhalation Calculations. J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> . <sup>1</sup> Department of Radiation Therapy, University of Sydney, Sydney, NSW, Australia; <sup>2</sup> Department of Physics, University of Sydney, Sydney, NSW, Australia.
50-10-200-7	Robust Functional Change Due to Radiation Therapy Dependency Due to the 4D Ventilation and MIP Correlation. J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> . <sup>1</sup> Department of Radiation Therapy, University of Sydney, Sydney, NSW, Australia; <sup>2</sup> Department of Physics, University of Sydney, Sydney, NSW, Australia.	50-10-200-7	Robust Evaluation of Lung Function Using 4DCT Ventilation Imaging. J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> . <sup>1</sup> Department of Radiation Therapy, University of Sydney, Sydney, NSW, Australia; <sup>2</sup> Department of Physics, University of Sydney, Sydney, NSW, Australia.
50-10-200-8	Single Shot Correlation to Systematic MIP Ventilation and MIP Ventilation Planning Using Pulmonary Function Test (PFT) Data. J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> . <sup>1</sup> Department of Radiation Therapy, University of Sydney, Sydney, NSW, Australia; <sup>2</sup> Department of Physics, University of Sydney, Sydney, NSW, Australia.	50-10-200-8	Validation of Lung Function Using 4DCT Ventilation Imaging. J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> . <sup>1</sup> Department of Radiation Therapy, University of Sydney, Sydney, NSW, Australia; <sup>2</sup> Department of Physics, University of Sydney, Sydney, NSW, Australia.
50-10-200-9	CT Ventilation Imaging: The New Clinical Reality of Functional Dosimetry and Response Assessment in Lung Cancer Radiation Therapy. J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> . <sup>1</sup> Department of Radiation Therapy, University of Sydney, Sydney, NSW, Australia; <sup>2</sup> Department of Physics, University of Sydney, Sydney, NSW, Australia.	50-10-200-9	Correlating Lung PFT with Ventilation Based and No-CT Based Ventilation. J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> . <sup>1</sup> Department of Radiation Therapy, University of Sydney, Sydney, NSW, Australia; <sup>2</sup> Department of Physics, University of Sydney, Sydney, NSW, Australia.
50-10-200-10	Quantitative Ventilation: Global Metrics and Relationships for CT Ventilation. J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> . <sup>1</sup> Department of Radiation Therapy, University of Sydney, Sydney, NSW, Australia; <sup>2</sup> Department of Physics, University of Sydney, Sydney, NSW, Australia.	50-10-200-10	Ventilation CT Based Lung Cancer Correlation with Response Assessment. J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> . <sup>1</sup> Department of Radiation Therapy, University of Sydney, Sydney, NSW, Australia; <sup>2</sup> Department of Physics, University of Sydney, Sydney, NSW, Australia.
50-10-200-11	The VAMPIRE Challenge: National Results from a Multi-Institutional Study of CT Ventilation Image Accuracy. J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> . <sup>1</sup> Department of Radiation Therapy, University of Sydney, Sydney, NSW, Australia; <sup>2</sup> Department of Physics, University of Sydney, Sydney, NSW, Australia.	50-10-200-11	Feasibility of Single-Shot Multi-Plane Range Errors CT for High Resolution Imaging of Regional Lung Ventilation. J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> . <sup>1</sup> Department of Radiation Therapy, University of Sydney, Sydney, NSW, Australia; <sup>2</sup> Department of Physics, University of Sydney, Sydney, NSW, Australia.
50-10-200-12	Building the Sydney Ventilation and CT Ventilation Australian Radiation Therapy (VAMPIRE) Challenge. J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> . <sup>1</sup> Department of Radiation Therapy, University of Sydney, Sydney, NSW, Australia; <sup>2</sup> Department of Physics, University of Sydney, Sydney, NSW, Australia.	50-10-200-12	4DCT Ventilation: A New Imaging Modality for Personalized Radiation Therapy. J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> . <sup>1</sup> Department of Radiation Therapy, University of Sydney, Sydney, NSW, Australia; <sup>2</sup> Department of Physics, University of Sydney, Sydney, NSW, Australia.
50-10-200-13	Validation of the Sydney Ventilation and CT Ventilation Australian Radiation Therapy (VAMPIRE) Challenge. J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> . <sup>1</sup> Department of Radiation Therapy, University of Sydney, Sydney, NSW, Australia; <sup>2</sup> Department of Physics, University of Sydney, Sydney, NSW, Australia.	50-10-200-13	Robust Evaluation of Lung Function Using 4DCT Ventilation Imaging. J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> , J. Fain <sup>1</sup> . <sup>1</sup> Department of Radiation Therapy, University of Sydney, Sydney, NSW, Australia; <sup>2</sup> Department of Physics, University of Sydney, Sydney, NSW, Australia.

### Goals and barriers for cross-modality validation

AAPM abstracts with "ventilation" in the title, many focusing on validation:

<p><b>10.10.2014</b> Design and Development of a Non-Rigid Free-breathing 4D Quantitatively Evaluating CT Based Pulmonary Ventilation Imaging. [Fischler<sup>1*</sup>, Hargrett<sup>2</sup>, Chen<sup>1,3</sup>, Liu<sup>1,3</sup>, O'Connell<sup>1,4</sup>, Sun<sup>1,4</sup>] (1)University of California, Berkeley, San Diego; (2)National Cancer Center, Australia, China; (3)University of California, Berkeley, Berkeley; (4)Lawrence Livermore National Laboratory, Livermore, CA</p>	<p><b>10.10.2014</b> Investigating Pulmonary Ventilation Patterns in Healthy Subjects Using Dynamic Computed Tomography. [Khanlou<sup>1*</sup>, Liu<sup>1</sup>, Chen<sup>1,2</sup>, Gao<sup>1</sup>, Hargrett<sup>1</sup>, Fishler<sup>1</sup>, Chen<sup>1,3</sup>, Liu<sup>1,3</sup>, O'Connell<sup>1,4</sup>, Sun<sup>1,4</sup>] (1)University of California, Berkeley, Berkeley, CA; (2)Lawrence Livermore National Laboratory, Livermore, CA; (3)National Cancer Center, Australia; (4)Lawrence Livermore National Laboratory, Livermore, CA</p>
<p><b>10.10.2014</b> Predicting Ventilation Change Due to Radiation Therapy: Importance for the 4D Ventilation and What Comes Next? [Fisher<sup>1*</sup>, Liu<sup>2</sup>, O'Connell<sup>3</sup>, Chen<sup>3</sup>, Gao<sup>4</sup>, Hargrett<sup>5</sup>] (1)University of Missouri, Columbia, MO; (2)University of Iowa, Iowa City, IA</p>	<p><b>10.10.2014</b> Quantifying Ventilation Change Due to Radiation Therapy Using 4DCT Acquisition Calibration. [Fisher<sup>1*</sup>, Liu<sup>2</sup>, O'Connell<sup>3</sup>, Chen<sup>3</sup>, Gao<sup>4</sup>, Hargrett<sup>5</sup>] (1)University of Missouri, Columbia, MO; (2)University of Iowa, Iowa City, IA; (3)University of Illinois, Urbana-Champaign, Urbana, IL</p>
<p><b>10.10.2014</b> CT Ventilation Imaging: The New Clinical Reality of Functional Assessment and Response Assessment in Lung Cancer. [Nelson<sup>1*</sup>, Hargrett<sup>2</sup>, Fischler<sup>3</sup>, Hargrett<sup>4</sup>, Chen<sup>1,5</sup>, Liu<sup>1,5</sup>, O'Connell<sup>1,6</sup>, Sun<sup>1,6</sup>] (1)University of California, Davis, California, CA; (2)University of California, San Diego, CA; (3)University of Missouri, Columbia, MO; (4)The University of Texas, Dallas, TX; (5)The University of California, Berkeley, CA; (6)Lawrence Livermore National Laboratory, Livermore, CA</p>	<p><b>10.10.2014</b> Validation of Lung Free-Flow for CT Ventilation Imaging. [O'Connell<sup>1*</sup>, Gao<sup>2</sup>, Fisher<sup>3</sup>, Liu<sup>1,4</sup>, Hargrett<sup>5</sup>, Hargrett<sup>6</sup>, Fishler<sup>1</sup>, Chen<sup>1,3</sup>, Liu<sup>1,3</sup>, O'Connell<sup>1,4</sup>, Sun<sup>1,4</sup>] (1)University of Missouri, Columbia, MO; (2)The University of Texas, Dallas, TX; (3)The University of California, Berkeley, CA; (4)Lawrence Livermore National Laboratory, Livermore, CA; (5)University of Iowa, Iowa City, IA; (6)Lawrence Livermore National Laboratory, Livermore, CA</p>
<p><b>10.10.2014</b> CT Ventilation Imaging: The New Clinical Reality of Functional Assessment and Response Assessment in Lung Cancer. [Nelson<sup>1*</sup>, Hargrett<sup>2</sup>, Fischler<sup>3</sup>, Hargrett<sup>4</sup>, Chen<sup>1,5</sup>, Liu<sup>1,5</sup>, O'Connell<sup>1,6</sup>, Sun<sup>1,6</sup>] (1)University of California, Davis, California, CA; (2)University of California, San Diego, CA; (3)University of Missouri, Columbia, MO; (4)The University of Texas, Dallas, TX; (5)The University of California, Berkeley, CA; (6)Lawrence Livermore National Laboratory, Livermore, CA</p>	<p><b>10.10.2014</b> Correlating Lung CT with Radiobiology Based and the CT Based Radiation Dose. [Liu<sup>1*</sup>, Fisher<sup>2</sup>, Hargrett<sup>3</sup>, O'Connell<sup>4</sup>, Gao<sup>5</sup>, Hargrett<sup>6</sup>, Fishler<sup>1</sup>, Chen<sup>1,3</sup>, Liu<sup>1,3</sup>, O'Connell<sup>1,4</sup>, Sun<sup>1,4</sup>] (1)University of Missouri, Columbia, MO; (2)The University of Texas, Dallas, TX; (3)The University of California, Berkeley, CA; (4)Lawrence Livermore National Laboratory, Livermore, CA; (5)University of Iowa, Iowa City, IA; (6)Lawrence Livermore National Laboratory, Livermore, CA</p>
<p><b>10.10.2014</b> Multiplanar CT Ventilation Imaging: Pre-Skills, Validation and Clinical Translation. [Fischler<sup>1*</sup>, Liu<sup>2</sup>, O'Connell<sup>3</sup>, Chen<sup>3</sup>, Liu<sup>1,3</sup>, O'Connell<sup>1,4</sup>, Sun<sup>1,4</sup>] (1)University of Missouri, Columbia, MO; (2)University of Iowa, Iowa City, IA; (3)University of Illinois, Urbana-Champaign, Urbana, IL; (4)Lawrence Livermore National Laboratory, Livermore, CA</p>	<p><b>10.10.2014</b> Nonrigid Single-Shot Multi-Plane Image Based CT for High-Resolution Imaging of Regional Lung Ventilation in Humans. [O'Neil<sup>1*</sup>, Hargrett<sup>2</sup>, Fischler<sup>3</sup>, Hargrett<sup>4</sup>, Chen<sup>1,5</sup>, Liu<sup>1,5</sup>, O'Connell<sup>1,6</sup>, Sun<sup>1,6</sup>] (1)University of California, Davis, CA; (2)University of California, San Diego, CA; (3)University of Missouri, Columbia, MO; (4)The University of Texas, Dallas, TX; (5)The University of California, Berkeley, CA; (6)Lawrence Livermore National Laboratory, Livermore, CA</p>
<p><b>10.10.2014</b> The Current Design: Radiation Fields from a Bulk Irradiated Bank of CT Ventilation Image Acquired by ESRF. [Fischler<sup>1*</sup>, Liu<sup>2</sup>, O'Connell<sup>3</sup>, Chen<sup>3</sup>, Liu<sup>1,3</sup>, O'Connell<sup>1,4</sup>, Sun<sup>1,4</sup>] (1)University of Missouri, Columbia, MO; (2)University of Iowa, Iowa City, IA; (3)University of Illinois, Urbana-Champaign, Urbana, IL; (4)Lawrence Livermore National Laboratory, Livermore, CA</p>	<p><b>10.10.2014</b> 4DCT Ventilation: A Novel Imaging Modality for Personalized Radiotherapy. [Fischler<sup>1*</sup>, Liu<sup>2</sup>, O'Connell<sup>3</sup>, Chen<sup>3</sup>, Liu<sup>1,3</sup>, O'Connell<sup>1,4</sup>, Sun<sup>1,4</sup>] (1)University of Missouri, Columbia, MO; (2)University of Iowa, Iowa City, IA; (3)University of Illinois, Urbana-Champaign, Urbana, IL; (4)Lawrence Livermore National Laboratory, Livermore, CA</p>

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### Goals and barriers for cross-modality validation

Variable results across different clinical / pre-clinical validation studies:

Study	Modality	Subjects	Key finding
Yamamoto et al. [1]	PFT	15 human subjects	Moderate correlations (range 0.43-0.73) between CT ventilation-defined

SAM hint: Are these studies directly comparable?

- Different subjects,
- Different 4DCT protocols,
- Different validation metrics,
- Different "ground truth" ventilation modalities.

Abbreviations: PFT = pulmonary function test, <sup>99m</sup>Tc-DTPA = technetium-99m-labeled diethyleneamine pentaacetate, DSC = Dice similarity coefficient.

S. Kidd et al. (2016) Radiother Oncol 118 (3) pg. 521-527

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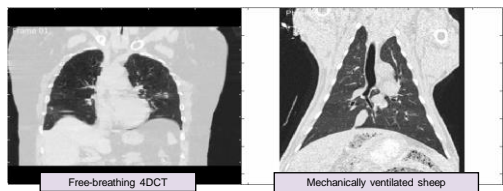
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### Goals and barriers for cross-modality validation

90% of clinical 4DCT scans suffer image artifacts due to irregular breathing. Yamamoto et al. (2008) IJROBP 72 (4) 1250-1258



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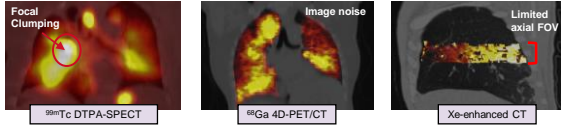
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**Goals and barriers for cross-modality validation**

› Different clinical ventilation images have different pros/cons in terms of image quality:




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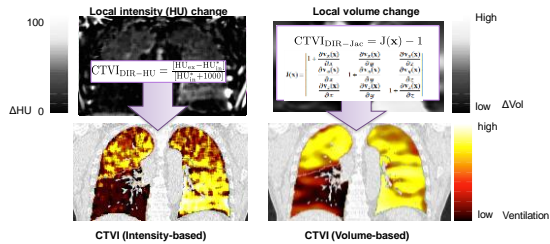
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**Goals and barriers for cross-modality validation**

› There are multiple methods to quantify breathing-induced air volume change using DIR:




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**Goals and barriers for cross-modality validation**

› And other user-selected parameters:

What 4DCT smoothing filter?

Which DIR engine / transform model?

Which DIR quality metric?

What segmentation method?

What DIR resolution?

How many 4DCT phase images for DIR?

How much DIR regularization?

There is a need for common datasets to objectively benchmark different CTVI algorithms under different imaging conditions

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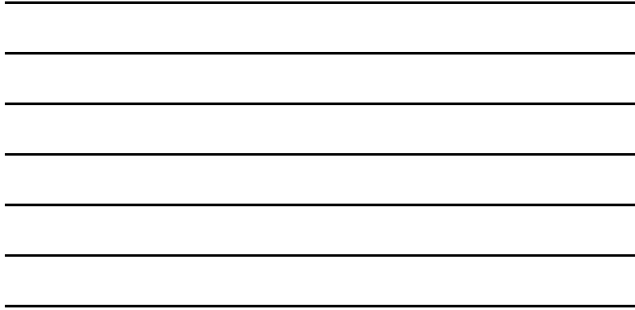
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Outline

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- › VAMPIRE: Realizing a multi-institutional validation dataset for CTVI
- › VAMPIRE Challenge: Preliminary results based on USYD algorithm

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VAMPIRE: Realizing a common validation dataset

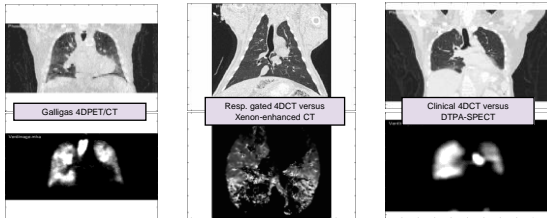
- “Ventilation Archive for Medical Pulmonary Image Registration Evaluation”  
50 pairs of 4DCT and ‘ground truth’ ventilation scans from three institutions (more soon)

 <p><b>Ventilation/Perfusion Post-tumor Emulsion Tomography - Based Assessment of Radiation Injury to Lung</b></p> <p>Chang-Ping He, PhD, Y. Richard Haskar, PhD, Thomas Dohn, PhD, Nathan Bromus, MD, Jason Calman, MSc, MSc (Medical), Michael P. Frieboes, PhD, Grant A. McEwen, PhD, Peter Poulsen, PhD, Andrew D. Wells, PhD, David Schwartz, PhD, Ronald L. Ma, MD, and Richard S. Beckett, MS</p> <p>Journal: <i>Journal of Nuclear Medicine</i>, 56(10), October 2015, pp. 1683-1690</p> <p><b>S. Siva et al. (2015) LIRCSP 53 (2) pg. 406-17</b></p>	 <p><b>Registration-based estimate of local lung tissue response compared to xenon CT measures of specific ventilation</b></p> <p>Journal: <i>Medical Image Analysis</i>, 12(6), pp. 752-63</p> <p><b>J. Reinhardt et al. (2008) Med. Imag. Analysis 12 (6) pg. 752-63</b></p>	 <p><b>Pulmonary Ventilation Imaging Based on 4-Dimensional Computed Tomography: Comparison With Pulmonary Function Tests and SPECT Ventilation Images</b></p> <p>Richard L. Beckett, PhD, Sam Akin, PhD, Cristian Lavaca, PhD, Erik Moller, MS, PhD, Eileen S. Jang, MS, Richard Cheng, BS, Susanna Egan, BS, Stephanie T. Jo, BS, Washington Salter, MD, PhD, Ming Ye, MD, PhD, and Paul D. Stein, PhD</p> <p>Journal: <i>Journal of Nuclear Medicine</i>, 54(9), September 2013, pp. 1623-1632</p> <p><b>T. Yamamoto et al. (2014) LIRCSP 50 (2) pg. 414-22</b></p>
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**THE UNIVERSITY OF SYDNEY** VAMPIRE: Realizing a common validation dataset

- VAMPIRE includes 4DCT / ground truth imaging acquired under different conditions:




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**THE UNIVERSITY OF SYDNEY** VAMPIRE: Realizing a common validation dataset

Image quality++ →

Image quality++ ↓	CT/IGT Modalities	DTPA	Technegas	Galligas	Xenon CT	MAA	Hyp. Gas
		V-SPECT	V-SPECT	4DPET/CT		Q-SPECT	MRI
	4D cone-beam CT	-	-	-	-	-	-
	Low-dose 4DCT	-	-	25	-	-	-
	Treatment planning 4DCT	21	-	-	-	-	-
	Regularity gated 4DCT	-	-	-	4	-	-
	Breath hold CT	-	-	-	-	-	-

LEGEND: Inaugural VAMPIRE Challenge† N/A

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**THE UNIVERSITY OF SYDNEY** VAMPIRE: Realizing a common validation dataset

Image quality++ →

Image quality++ ↓	CT/IGT Modalities	DTPA	Technegas	Galligas	Xenon CT	MAA	Hyp. Gas
		V-SPECT	V-SPECT	4DPET/CT		Q-SPECT	MRI
	4D cone-beam CT	-	11	-	-	11	-
	Low-dose 4DCT	-	-	25	-	-	-
	Treatment planning 4DCT	21	11	18	-	32	-
	Regularity gated 4DCT	-	-	-	4	-	-
	Breath hold CT	-	-	18	-	-	Up to 70

LEGEND: Inaugural VAMPIRE Challenge† VAMPIRE II (Date TBA) N/A

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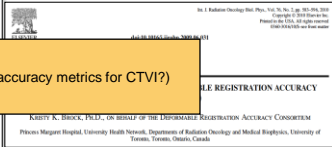
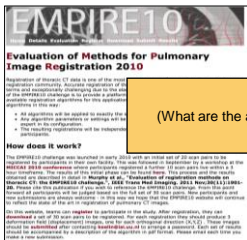
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UNIVERSITY OF SYDNEY Inaugural VAMPIRE Challenge

- The VAMPIRE Challenge is inspired by MIDRAS & EMPIRE10 (<http://empire10.isi.uu.nl>)



(What are the accuracy metrics for CTVI?)

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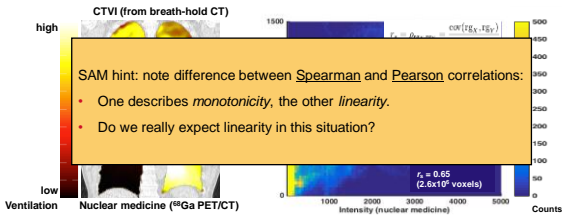
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UNIVERSITY OF SYDNEY Inaugural VAMPIRE Challenge

› We want high Spearman correlation (" $r_s$ " or " $\rho$ ") with clinical ventilation imaging.

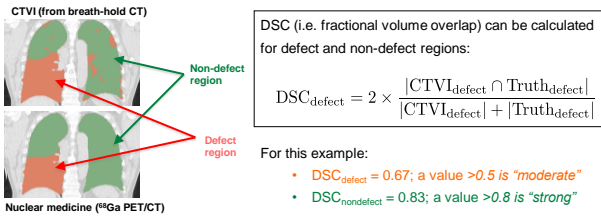


22

Horizontal lines for notes.

UNIVERSITY OF SYDNEY Inaugural VAMPIRE Challenge

› We also want overlap of defect regions: Dice similarity coefficient (DSC)



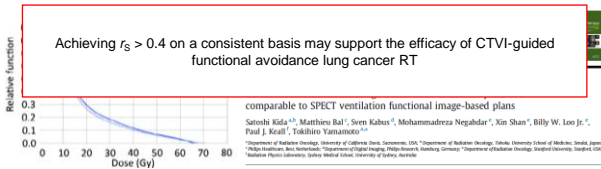
23

Horizontal lines for notes.

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What is a "good" correlation?

› Kida *et al.* demonstrated that  $r_s \sim 0.4$  between CTVI and SPECT can produce comparable functionally adaptive treatment plans:



S. Kida *et al.* (2016) *Radiother Oncol* 118 (3) pp. 521-527

24

Horizontal lines for notes.



**UNIVERSITY OF SYDNEY** Inaugural VAMPIRE Challenge

What is a "good" correlation?

- We found  $r_s = (0.66 \pm 0.19)$  when comparing V/Q-SPECT images for 11 patients with matched ventilation/perfusion.

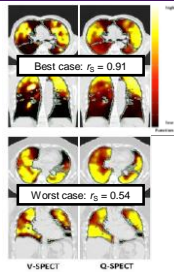


Image courtesy Dr Fiona Hegi-Johnson (Nepean Hospital, NSW Australia)

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**UNIVERSITY OF SYDNEY** Inaugural VAMPIRE Challenge

What is the structure of the VAMPIRE Challenge? (And how to take part)

- Download the VAMPIRE Challenge Dataset**
  - Email [john.kipritidis@sydney.edu.au](mailto:john.kipritidis@sydney.edu.au) to register.
  - Receive link to Dicom or MetalImage (MHA) download.
  - Dataset divided into "Training" / "Validation" components (30% / 70% split).  
*(Ground truth ventilation provided for Training component only)*
- Upload your CTVI results:**
  - DIR motion fields
  - Processed CTVIs
  - Answer a multiple-choice survey to characterize your algorithm
  - Deadline is October, 2016.
- Voxel-based correlations performed at University of Sydney (+ others):**
  - Focus on Spearman  $r_s$  and DSC values for defect/non-defect regions
  - Determine which CTVI algorithm(s) achieve the best spatial accuracy

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**UNIVERSITY OF SYDNEY** Inaugural VAMPIRE Challenge

- 12 participating groups (so far!) using various commercial / open-source DIR software:




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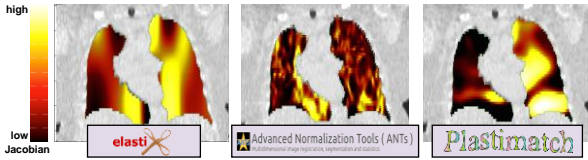
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**UNIVERSITY OF SYDNEY** Inaugural **VAMPIRE** Challenge

- o Different DIR software can produce quite different lung deformation (Jacobian) maps:



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**VESPIR** (Ventilation via Scripted Pulmonary Image Registration)

Sub-function	Options / Features
(1) File import	o Supports DICOM / MHA files
(2) Image cropping <sup>1</sup>	o GUI-based ROI selection
(3) Gaussian filtering <sup>2</sup>	o FWHM selection
(4) Lung segmentation <sup>3</sup>	o Selection of intensity levels for air/water/lung <sup>1</sup> o Peak-exhale/inhale selection <sup>3</sup> o Allow mask import from file
(5) Deformable Image Registration (DIR)	o Supports <b>BSplines</b> DIR used in <b>elastiX</b> o Supports <b>FreeSurf</b> scheme: <b>Initial/Global/Ref</b> o Supports <b>MMIO</b> -based DIR both with symmetric lung masks o Adjustable DIR regularization o 1-6 DIR resolution stages <sup>4</sup> o Supports user parameter files
(6) Ventilation quantification	o Supports four CTVI metrics (intensity or volume based) o Supports 4D time-averaging <sup>5</sup> o Mask-preserving median filter <sup>6</sup> o Avoidance map generation <sup>6</sup> o Discard output <sup>7</sup>
(7) Validation of DIR and/or CTVI <sup>8</sup>	o In-built visual DIR evaluation o Spearman correlation of CTVI with clinical ventilation scan

Kipritidis et al. (2016)  
2016 ISBI pg. 939-942

We tested a number of different CTVI calculations:

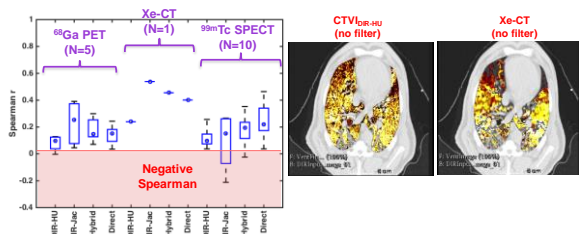
Metric	Expression
CTVI <sub>intensity</sub>	$\frac{HU_{inh}(x) - HU_{ex}(x)}{HU_{inh}(x) + HU_{ex}(x) + 1000}$
CTVI <sub>intensity-jac</sub>	$Jac(x, v) - 1$
CTVI <sub>intensity</sub>	$[HU_{inh}(x) / Jac(x, v) - HU_{ex}(x)]$
CTVI <sub>Direct</sub>	$\sum_{i=1}^N \frac{[HU_{inh}(x) \times HU_{ex}(x) + 1000]}{-1000} / N$

(No algorithm "tuning" per se; visual checking of DIR)



**UNIVERSITY OF SYDNEY** Preliminary **VAMPIRE** Challenge results (**VESPIR**)

- o Spearman correlations (Training data only)

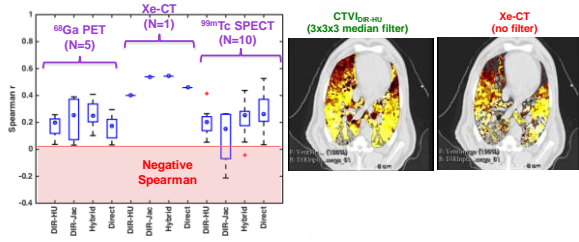


30

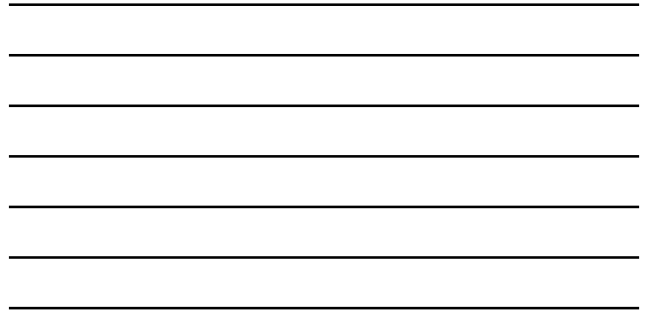


UNIVERSITY OF SYDNEY Preliminary VAMPIRE Challenge results (VESPIR)

- Spearman correlations (Training data only)

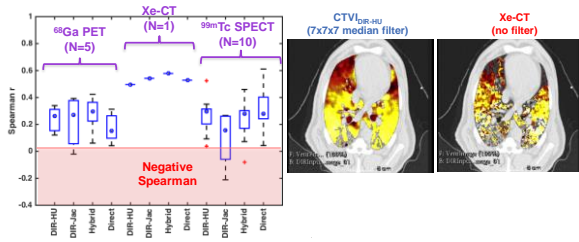


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UNIVERSITY OF SYDNEY Preliminary VAMPIRE Challenge results (VESPIR)

- Spearman correlations (Training data only)

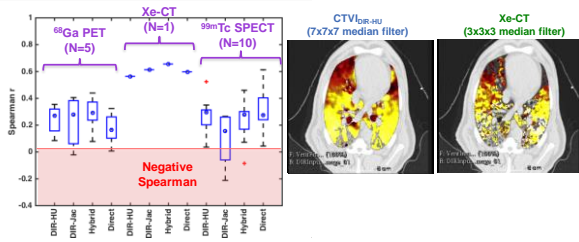


32



UNIVERSITY OF SYDNEY Preliminary VAMPIRE Challenge results (VESPIR)

- Spearman correlations (Training data only)

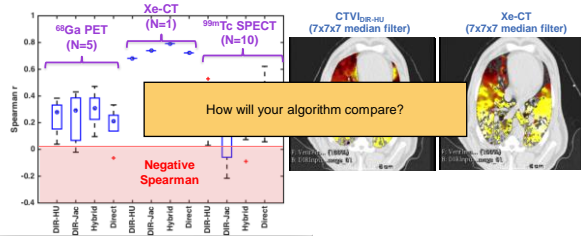


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**UNIVERSITY OF SYDNEY** Preliminary VAMPIRE Challenge results (VESPIR)

o Spearman correlations (Training data only)



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**UNIVERSITY OF SYDNEY** Inaugural VAMPIRE Challenge

What are the benefits of participating in the VAMPIRE Challenge?

**Benefit of providing your CTVI outputs:**

- Learn how your CTVI algorithm fares against others.

**Benefit of providing data:**

- Learn which CTVI methods are most accurate for your imaging data.

**Following each VAMPIRE Challenge:**

- Where possible, full data will be publically released for purposes of CTVI validation

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**UNIVERSITY OF SYDNEY** Take home message

- › Validation remains a core focus of CTVI research.
- › The VAMPIRE dataset will begin to address the need for common validation datasets.
- › Please contact us to participate in the Inaugural VAMPIRE Challenge  
→ Email [john.kipritidis@sydney.edu.au](mailto:john.kipritidis@sydney.edu.au) to take part!

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- Nicholas Hardcastle



- Joseph M. Reinhardt
- Gary E. Christensen



- Bill W. Loo



- Takihiro Yamamoto



- Bilal Tahir
- Jim Wild
- Rob Ireland



- Kristy Brock
- Guillaume Cazoulat

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