Tumor Detection by Simultaneous Bilateral DOT Breast Imaging

Yaling Pei,[1] Harry L. Graber,[1,2] Mark B. Farber,[2] Christoph H. Schmitz,[1,2] Yong Xu,[1,2] Paul Toubas,[2] Naresh Patel,[2] Michael Katz,[3] William B. Solomon[4] and Randall L. Barbour[1,2]

[1]NIRx Medical Technologies, LLC., 15 Cherry Lane, Glen Head, NY 11545 US

Departments of [2]Pathology, [3]Surgery, and [4]Internal Medicine, SUNY Downstate Medical Center, 450 Clarkson Avenue, Box 25, Brooklyn, NY 11203 US

ypei@nirx.net

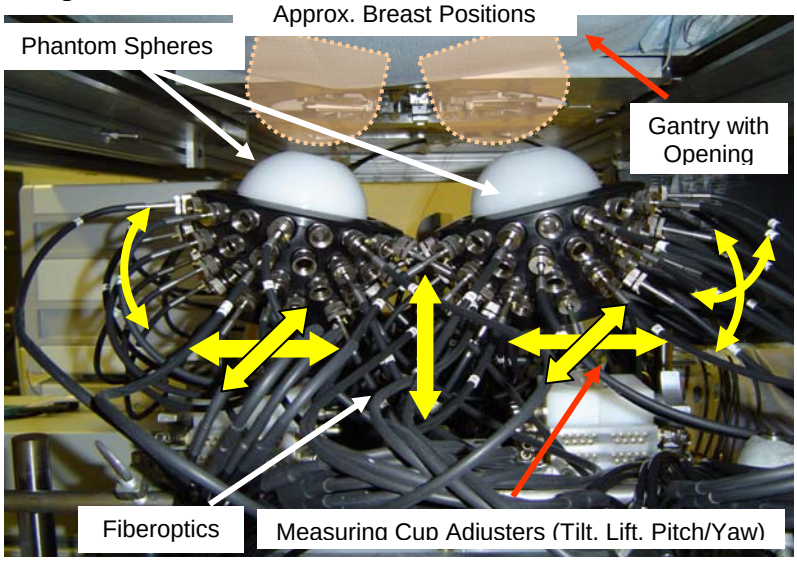
Abstract: We have constructed a 64 channel dual breast imager for simultaneous bilateral time-series detection. Studies on 37 subjects (14 with cancer) shows that tumor detection and localization is possible with high sensitivity and specificity.

OCIS codes: (100.6950) Tomographic imaging processing; (100.6890) Three-dimensional image processing; (120.3890) Medical optics instrumentation.

1. Introduction

Growth of solid tumors is frequently accompanied by marked changes in the vascular supply sustaining tumor growth. Frequently, this produces a state of impaired perfusion and a relative hypoxic environment. To image these and related features we have developed a dual-breast DOT imaging system capable of simultaneous bilateral measurements [1]. Figure 1 shows a photograph of the measuring head employed. Dual-wavelength DOT images were collected at 2 Hz during baseline periods and while subjects were asked to perform a Valsalva maneuver as a means to provoke a vascular response. Subjects from the two groups were aged matched and matched to body mass index. Features extracted from the computed Hb image time series were separated in accordance to the expected influence that hypoxic tumor environments can have on vascular reactivity (e.g., metrics sensitive to enhanced vasomotion, Group 1 data) its temporal coordination, (reduced coherence, Group 2 data) and on induced venous congestion caused by the Valsalva maneuver (enhanced vasoengorgement, delayed reperfusion, Group 3 data). For each data group and Hb state, multiple metrics were identified and each were computed according to multiple formulations providing a total of 138 measures per individual per breast. The corresponding values were subsequently tested for mean differences between the affected and healthy breast among the cancer group and between the two patients groups using both univariate and multivariate methods for the purpose of quantifying the diagnostic predictive values appropriate to tumor detection, and other measures for tumor localization and sizing.

Figure 1



2. Results

2.1. Tumor Detection: Results in Table 1 summarize findings of computed diagnostic predictors derived using the logistic regression method and implemented with and without employing leave-out-one-cross-validation (LOOCV). Values shown that include group 3 data are based on an N of 21 (10 cancer, 11 healthy), owing to the fact that only a subset of all subjects were able to correctly perform the Valsalva maneuver. Inspection shows that for this subgroup, predictive values are >70% for all categories depending on considered metrics, and >87% when data groups 1 and 3 are considered together. When all subjects are considered (N=37), for group 1 and 2 data only, predictive values range from 67-90%.

Table 1:

Formulation	$N_{subjects}$	$N_{metrics}$	Hb States Included	Data Groups Included	Sens. (%)	Spec. (%)	PPV (%)	NPV (%)	
Diff./Max.	21	3	Oxy (2), Total (1)	1, 3	100	90.9	90.1	100	All Subjects
					87.5	90.0	87.5	90.0	LOOCV[a]
Diff.*Max	21	3	Oxy (1), Deoxy (1), Total (1)	1, 2, 3	100	81.8	83.3	100	All Subjects
					70.0	90.0	87.5	75.0	LOOCV
Diff.*Max.	37	5	Oxy (3), Deoxy (1), Total (1)	1, 2	100	87.0	82.4	100	All Subjects
					85.7	73.9	66.7	89.5	LOOCV

2.2. Tumor localization: Tumor localization was explored on different spatial scales. On the grossest level, we determined the accuracy by which we can correct identify which of the two breasts contains the tumor assuming no prior knowledge. Additionally, the same determination was made but on the level of a breast quadrant. Using this approach it is possible to assign the tumor to the incorrect breast. Results showed that when findings from several measures were spatially superimposed and a threshold imposed, the accuracy of tumor assignment on the spatial scale of the whole breast was 100% for those subjects who could correctly perform the Valsalva maneuver (N=11). The corresponding values at the level of the breast quadrant were 55% for correct quadrant, 36% adjacent quadrant but correct breast, 0% opposite quadrant and 9% incorrect breast.

2.3. Tumor Sizing: Using 50% of maximum value in the image maps as the thresholding criteria for considered metrics, we have estimated tumor volume (Table 2) based those subjects for whom at least one measure correctly identified the tumor quadrant (N=8). In the case of HbO_2 Saturation, the correlation between estimated and actual tumor size was 0.79.

3. Summary

Among a total of 138 metrics explored from time-series measures of Hb states obtained from baseline and provocation maneuvers, 58% were determined as having means values significantly different between healthy and tumor bearing breasts. The nature of these differences point to an underlying hypoxic environment in tumor breasts with enhanced temporal dis-coordination and sluggish perfusion. Depending on which combination of metrics are examined, the diagnostic predictive values computed

using cross-validation methods ranged from 67-100%. Tumor localization on the whole breast level was optimal (100%) based on measures derived from the Valsalva maneuver.

Table2:

Subject No.	Estimated tumor size						Actual tumor size	
	Hb_{Oxy}		Hb_{Deoxy}		HbO_2 Saturation		Estimated volume[b] (cm^3)	Size (cm)
	Volume (cm^3)	Diameter[a] (cm)	Volume (cm^3)	Diameter[a] (cm)	Volume (cm^3)	Diameter[a] (cm)		
2	3.64	1.91	4.65	2.07	7.07	2.38	14.1	2×3
4	2.42	1.67	- -	- -	- -	- -	84.0	7×4×3
8	3.23	1.83	3.43	1.87	5.86	2.24	14.1	3.0
9	0.20	0.73	- -	- -	0.61	1.05	8.18	2.5
11	- -	- -	3.64	1.91	2.63	1.71	4.50	2×1.5×1.5
12	1.62	1.46	1.62	1.46	- -	- -	0.27	0.7×0.8
13	- -	- -	1.82	1.51	3.84	1.94	3.00	2×1.5×1
14	3.64	1.91	2.02	1.57	4.24	2.01	6.00	3×2×1

Reference

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