sure; transducer size; etc, as well as physical lesion-specific parameters such as: depth; size; geometry; etc. Through the comparisons made in Section 6.1, it is clear that shear wave speed quantification is the ideal ultrasound elastography modality with regards to detecting deep tissue injuries. Not only is shear wave speed quantification a quantifiable technology which would allow clinicians to directly track the progression of an injury over time, but it was found to consistently provide the most accurate results compared to both quasi-static elastography and ARFI imaging. Shear wave speed quantification is not without its limits however, as the acoustic radiation force impulses which give rise to deformation deep within tissue may not be large enough to be readily detected by the ultrasound machine. To overcome these limitations, the ultrasonic transmission power may be increased and the interrogation frequency may be decreased, but such measures may only go so far and have profound tissue health implications. Further, since only specific, localized regions of tissue may be interrogated using shear wave speed quantification, quasi-static ultrasound elastography or ARFI imaging may be used to image much larger regions of tissue in order to search for specific regions of interest. Although such "fishing" expeditions may not provide truly accurate and quantifiable data, they may guide the use of shear wave speed quantification to provide a more complete picture of tissue health.

From the work presented here, it is fully expected that ultrasound elastography is capable of becoming a clinical tool to be used in the early detection and monitoring of deep tissue injuries. The adoption of this technology for such a venture would have wide-ranging consequences from potentially increasing quality of life of at-risk patients, to decreasing the financial burden on the health care system, to even providing future avenues for deep tissue injury research—without a quality early deep tissue injury detection method, the bulk of deep tissue injury research focuses on late-stage ulcers for which treatments are often applied “too late”. With a firm understanding of the mechanics and principles involved with ultrasound elastography, the next stage in this technology’s development is to investigate its use in animal models where deep tissue injury lesions may be tightly controlled and the lesions can be co-investigated using MRI techniques. Once early deep tissue injury detection is well understood in living tissue, trials should move to at-risk human patients. Since ultrasound and subsequently ultrasound elastography are non-invasive tools with relatively inexpensive equipment, it is expected that clinical adoption will be swift once the technology is proven in human tissue. Although as of the time of writing there are commercially available ultrasound elastography systems, future work may also involve developing application-specific probes or even entire devices devoted to applying ultrasound elastography toward deep tissue injuries which can provide the necessary parameters to optimize detection and ease of use.

Ultrasound elastography is a powerful tool which through the numerical simulations performed in this work was found to be able to distinguish both early and late stage deep tissue injuries and may provide for the first ever clinical tool to reliably detect DTI with a thought toward improving patient care and quality of life.

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Appendix A

Data Tables

A.1 Quasi-Static Ultrasound Elastography

Table A.1: Data for Fig. 3.9

r_{lesion}	$E_{rel,nom}$			
(mm)	0.32	0.56	1.80	3.20
2.5	0.84	0.92	1.09	1.20
5.0	0.77	0.83	1.22	1.48
10.0	0.92	0.73	1.41	1.93
12.5	0.92	0.70	1.47	2.10

Table A.2: Data for Fig. 3.10

d	$E_{rel,nom}$			
(cm)	0.32	0.56	1.80	3.20
3.5	0.91	0.74	1.42	2.00
6.5	0.80	0.71	1.51	2.19
8.5	0.87	0.70	1.49	2.14
10.0	0.92	0.70	1.47	2.10

Table A.3: Data for Fig. 3.11

h	$E_{rel,nom}$			
(cm)	0.32	0.56	1.80	3.20
1.25	0.70	0.72	1.53	2.11
2.50	0.92	0.70	1.47	2.10
3.75	0.81	0.69	1.49	2.13

Table A.4: Data for Fig. 3.12

f	$E_{rel,nom}$			
(MHz)	0.32	0.56	1.80	3.20
2	0.67	0.72	1.47	2.06
4	0.92	0.70	1.47	2.10
8	0.71	0.69	1.47	2.09

Table A.5: Data for Fig. 3.13

ε_{app}	$E_{rel,nom}$			
(%)	0.32	0.56	1.80	3.20
2.5	0.85	0.77	1.40	1.98
5.0	0.92	0.70	1.47	2.10
10.0	1.34	0.93	1.35	1.20

Table A.6: Data for Fig. 3.14

δ_{sep}	$E_{rel,nom}$			
(cm)	0.32	0.56	1.80	3.20
1.25	0.78	0.86	1.18	1.40
1.50	0.77	0.86	1.19	1.39
1.75	0.76	0.85	1.19	1.41
2.00	0.75	0.84	1.20	1.42

Table A.7: Data for Fig. 3.16

b_r	$E_{rel,nom}$			
(mm)	0.32	0.56	1.80	3.20
1.0	0.93	0.69	1.49	2.17
2.5	0.93	0.87	1.51	2.24
5.0	0.91	1.00	1.52	2.30
7.5	0.91	1.00	1.50	2.28

Table A.8: Data for Fig. 3.17

b_ρ	$E_{rel,nom}$			
(cm^{-2})	0.32	0.56	1.80	3.20
10	0.78	0.79	1.29	1.66
20	0.85	0.73	1.38	1.87
30	0.86	0.71	1.42	1.96
40	0.76	0.71	1.43	1.99

Table A.9: Data for Fig. 3.19

r_{bl}	$E_{rel,nom}$			
(mm)	0.32	0.56	1.80	3.20
0.5	0.72	0.82	1.25	1.58
1.0	0.86	0.71	1.42	1.96
1.5	0.90	0.72	1.44	2.01

Table A.10: Data for Fig. 3.20

$\varnothing L$	$E_{rel,nom}$			
(cm)	0.32	0.56	1.80	3.20
0.5	1.15	1.17	1.17	1.26
1.0	1.01	1.09	1.21	1.28
2.0	0.83	0.93	1.21	1.49
2.5	0.76	0.88	1.25	1.59

Table A.11: Data for Fig. 3.22

d	$E_{rel,nom}$			
(cm)	0.32	0.56	1.80	3.20
6.5	0.68	0.75	1.13	1.46
6.75	0.77	0.81	1.18	1.51
7.25	0.76	0.88	1.25	1.59

A.2 Acoustic Radiation Force Impulse Imaging

Table A.12: Data for Fig. 4.4

Depth, d_f (cm)	Body Force at Focal Point, $F_{b,f}$ (kN m^{-3}) f = 1 MHz	f = 2 MHz	f = 4 MHz	f = 6 MHz
1	151.5	194.0	122.1	128.5
2	113.0	97.9	83.1	29.2
3	81.7	46.9	33.2	13.3
4	57.3	24.2	12.2	2.2
5	40.7	12.8	4.0	0.2
6	29.6	7.2	0.8	0.0
7	21.8	4.2	0.1	0.0
8	16.3	2.5	0.0	0.0
9	12.4	1.5	0.0	0.0

Table A.13: Data for Fig. 4.5

Frequency, f (MHz)	Body Force at Focal Point, $F_{b,f}$ (kN m^{-3}) $w_{active} = 4$ cm	$w_{active} = 8$ cm	$w_{active} = 10$ cm
1.0	55.3	85.0	96.6
1.5	19.1	25.9	24.7
2.0	15.3	18.0	12.5
3.0	16.4	10.2	5.6
4.0	1.0	0.3	0.1

Table A.14: Data for Fig. 4.6

n_c	$F_{b,f}$ (kN m^{-3})
3	0.2
100	2.6
300	7.2
500	7.3
700	7.3

Table A.15: Data for Fig. 4.5

Depth,	Body Force at Focal Point, $F_{b,f}$ ($\mathrm{kN\,m^{-3}}$)				
d_f (cm)	$P = 4\,\mathrm{MPa}$	$P = 5\,\mathrm{MPa}$	$P = 6\,\mathrm{MPa}$	$P = 7\,\mathrm{MPa}$	$P = 8\,\mathrm{MPa}$
3	66.7	103.5	147.8	199.3	257.5
4	34.4	53.5	76.6	103.4	133.9
5	18.1	28.2	40.4	54.5	70.6
6	10.3	16.0	22.9	30.9	40.0
9	2.1	3.3	4.7	6.4	8.3

Table A.16: Data for Fig. 4.8

Depth,	Spatial-Peak Pulse-Average Intensity, I_{SPPA} ($\mathrm{W\,cm^{-2}}$)			
d_f (cm)	$f = 1\,\mathrm{MHz}$	$f = 2\,\mathrm{MHz}$	$f = 4\,\mathrm{MHz}$	$f = 6\,\mathrm{MHz}$
1	1,992	1,705	1,399	1,465
2	1,400	749	388	347
3	982	321	182	140
4	673	154	151	137
5	478	117	146	110
6	352	95	142	118
7	265	103	128	120
8	206	79	126	106
9	165	64	159	100

Table A.17: Data for Fig. 4.9

Depth,	Maximum Induced Tissue Displacement, $\|v\|_{max}$ (µm)			
d_f (cm)	$f = 1\,\mathrm{MHz}$	$f = 2\,\mathrm{MHz}$	$f = 4\,\mathrm{MHz}$	$f = 6\,\mathrm{MHz}$
1	3.10	3.29	3.87	3.77
2	2.90	1.93	1.70	1.52
3	2.47	1.13	0.76	0.52
4	1.83	0.63	0.30	0.18
5	1.40	0.37	0.15	0.10
6	1.15	0.22	0.09	0.08
7	1.07	0.13	0.05	0.07
8	0.85	0.08	0.00	0.00
9	0.58	0.05	0.00	0.00

Table A.18: Data for Fig. 4.10

Depth, d_f (cm)	Maximum Induced Tissue Displacement, $\|v\|_{max}$ (µm)				
	$P = 4\,\text{MPa}$	$P = 5\,\text{MPa}$	$P = 6\,\text{MPa}$	$P = 7\,\text{MPa}$	$P = 8\,\text{MPa}$
3	1.61	2.52	3.62	4.93	6.44
4	0.90	1.40	2.02	2.75	3.59
5	0.52	0.81	1.17	1.60	2.09
6	0.31	0.49	0.70	0.95	1.24
9	0.07	0.10	0.15	0.20	0.26

Table A.19: Data for Fig. 4.11

Frequency, f (MHz)	Maximum Induced Tissue Displacement, $\|v\|_{max}$ (µm)		
	$P = 4\,\text{MPa}$	$P = 6\,\text{MPa}$	$P = 8\,\text{MPa}$
1	1.83	4.10	7.28
2	0.31	0.70	1.24
4	0.14	0.36	0.79
6	0.12	0.33	0.73

Table A.20: Data for Fig. 4.12

r_{lesion} (mm)	$E_{rel,nom}$			
	0.32	0.56	1.80	3.20
2.5	0.80	0.87	1.21	1.50
5.0	0.60	0.76	1.34	1.78
10.0	0.58	0.74	1.35	1.81
12.5	0.57	0.74	1.37	1.84

Table A.22: Data for Fig. 4.16

b_r (mm)	$E_{rel,nom}$			
	0.32	0.56	1.80	3.20
2.5	0.58	0.74	1.36	1.81
5.0	0.58	0.74	1.36	1.82
7.5	0.58	0.74	1.36	1.81

Table A.21: Data for Fig. 4.14

d (cm)	$E_{rel,nom}$			
	0.32	0.56	1.80	3.20
2	0.57	0.76	1.32	1.74
4	0.58	0.74	1.35	1.81
6	0.53	0.71	1.35	1.81
8	0.57	0.75	1.35	1.79

Table A.23: Data for Fig. 4.18

b_ρ (cm^{-2})	$E_{rel,nom}$			
	0.32	0.56	1.80	3.20
10	0.77	0.85	1.22	1.52
20	0.71	0.82	1.27	1.62
30	0.66	0.79	1.30	1.69
40	0.63	0.77	1.32	1.74

Table A.24: Data for Fig. 4.20

r_{bl}	$E_{rel,nom}$			
(mm)	0.32	0.56	1.80	3.20
0.5	0.85	0.91	1.15	1.37
1.0	0.66	0.79	1.30	1.69
1.5	0.60	0.75	1.34	1.78

Table A.25: Data for Fig. 4.22

$\varnothing L$	$E_{rel,nom}$			
(cm)	0.32	0.56	1.80	3.20
0.5	0.91	0.95	1.09	1.24
1.0	0.75	0.87	1.21	1.47
2.0	0.56	0.75	1.30	1.67
2.5	0.56	0.75	1.31	1.69

A.3 Shear Wave Speed Quantification

Table A.26: Data for Fig. 5.8

r_{lesion} (mm)	$E_{rel,nom}$ 0.32	0.56	1.80	3.20
2.5	0.75	0.81	1.07	1.21
5.0	0.47	0.68	1.26	1.48
10.0	0.20	0.58	1.57	3.35
12.5	0.06	0.53	1.65	4.18

Table A.27: Data for Fig. 5.10

Δ_{off} (cm)	$E_{rel,nom}$ 0.32	0.56	1.80	3.20
0.00	0.28	0.57	1.76	3.73
1.25	0.14	0.53	1.77	2.94
2.50	0.20	0.58	1.57	3.35
3.75	0.45	0.67	1.81	2.05

Table A.28: Data for Fig. 5.12

d (cm)	$E_{rel,nom}$ 0.32	0.56	1.80	3.20
2	0.49	0.68	1.63	3.97
4	0.20	0.58	1.57	3.35
6	0.36	0.56	1.90	3.47
8	0.87	0.28	1.25	1.74

Table A.29: Data for Fig. 5.14

b_r (mm)	$E_{rel,nom}$ 0.32	0.56	1.80	3.20
2.5	0.16	0.53	1.85	3.02
5.0	0.16	0.53	1.82	3.08
7.5	0.19	0.54	1.79	3.01

Table A.30: Data for Fig. 5.16

b_ρ (cm^{-2})	$E_{rel,nom}$ 0.32	0.56	1.80	3.20
10	0.73	0.82	1.32	1.70
20	0.59	0.73	1.48	2.17
30	0.49	0.68	1.58	2.34
40	0.44	0.63	1.62	2.42

Table A.31: Data for Fig. 5.18

r_{bl} (mm)	$E_{rel,nom}$ 0.32	0.56	1.80	3.20
0.5	0.73	0.82	1.32	1.70
1.0	0.59	0.73	1.48	2.17
1.5	0.49	0.68	1.58	2.34

Table A.32: Data for Fig. 5.20

$\varnothing L$ (cm)	$E_{rel,nom}$ 0.32	0.56	1.80	3.20
0.5	0.98	1.03	1.26	1.47
1.0	0.84	0.95	1.44	1.74
2.0	0.05	0.64	1.86	2.57
2.5	0.03	0.52	2.13	3.19