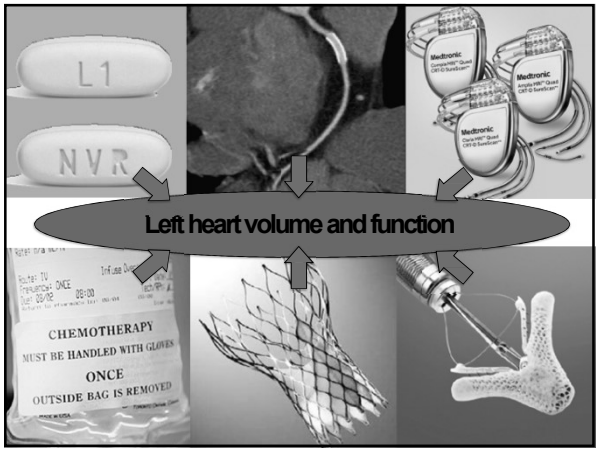
Automated Volume, EF, Strain Quantification

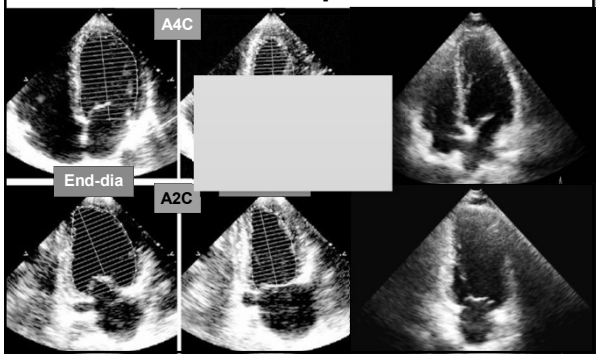
Prof Alex Lee

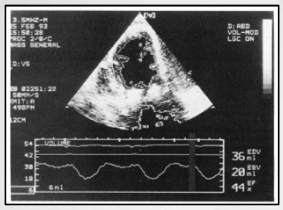
MD, MBChB, FACC, FESC, FRCP

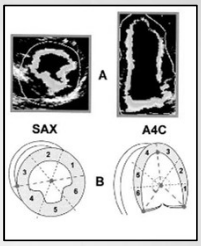
Echo 27-28 October 2018 SINGAPORE
www.echosingapore.com



2D Biplane method of disks Modified Simpson's rule



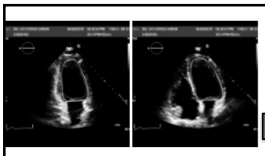




- Automated border detection and color kinesis by acoustic quantification in the 90's
- Heavily dependent on image quality and gain setting

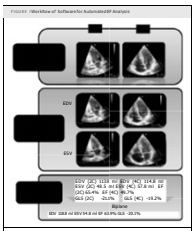
Morrissey, et al. JASE. 1994;7:107-115.
Lang, et al. Circulation. 1996;93:1877–1885

Faculty of Medicine
The Chinese University of Hong Kong

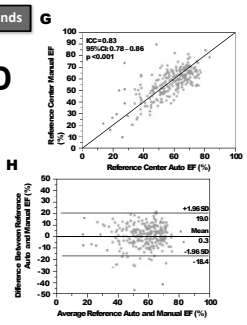


8 seconds

Auto 2D vs Manual 2D

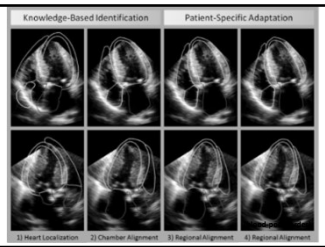


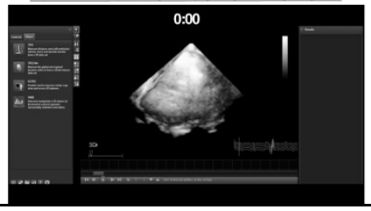
Fully Automated Versus Standard Tracking of Left Ventricular Ejection Fraction and Longitudinal Strain
The FAST-EFs Multicenter Study

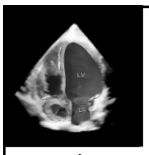


Knacksted, et al. J Am Coll Cardiol 2015;66:1456–66

Automated 3D vol and EF



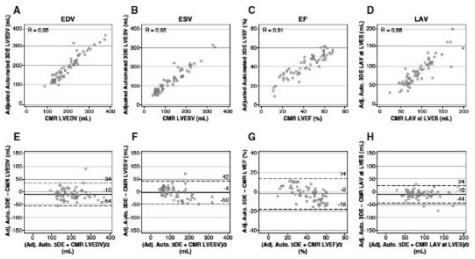




ORIGINAL RESEARCH

Auto 3D vs CMR

Transthoracic 3D Echocardiographic Left Heart Chamber Quantification Using an Automated Adaptive Analytics Algorithm

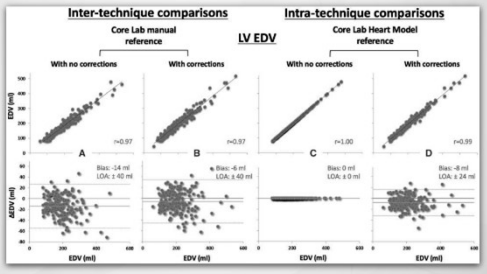


Tsang W, et al. JACC Cardiovasc Imaging. 2016

Manual 3D vs Auto 3D

ESC European Heart Journal - Cardiovascular Imaging (2018) 19, 47–58 doi:10.1093/ehjci/jex328

Three-dimensional echocardiographic quantification of the left-heart chambers using an automated adaptive analytics algorithm: multicentre validation study



Faculty of Medicine
The Chinese University of Hong Kong

D. Medvedofsky et al. EHJ-CVI. 2018

echoresearch and practice — Automated cardiac volumetric analysis — ID: 17-0023; December 2017 DOI: 10.1530/ERP-17-0023

RESEARCH

Automated left heart chamber volumetric assessment using three-dimensional echocardiography in Chinese adolescents

Mean age=17y
N=53

Table 2 HeartModel comparison vs expert manual 3DE measurements.

	HeartModel	Expert manual 3DE method	*P*	Bias	LOA (1.96 S.D.s)	Correlation
LVEDV (mL)	106.9 ± 21.2	96.6 ± 17.9	<0.001	10.2	12.0	0.965
LVESV (mL)	40.9 ± 10.8	36.7 ± 9.3	<0.001	4.1	6.2	0.962
LVEF (%)	62.2 ± 4.8	62.4 ± 4.4	0.381	−0.3	4.6	0.875
LAV at LVES (mL)	38.9 ± 8.8	36.5 ± 9.0	<0.001	2.4	7.4	0.908

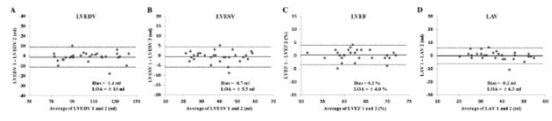
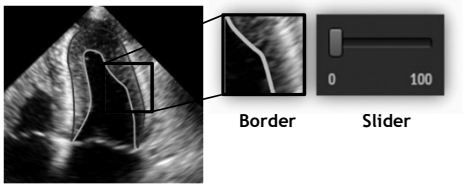


Figure 3
Test–retest reproducibility of HeartModel program, using Bland–Altman plot for LVEDV, LVESV, LVEF and LAV at LVES in 30 adolescent subjects.

Luo XX, Fang F, So HK, Liu C, Yam MC, Lee AP. *Echo Res Pract*. 2017;4:53-61

Endocardial Border Placement

- Algorithm detects both inner and outer myocardial borders
- Inner border is located at blood/tissue interface
- Outer border is located at compacted myocardium interface
- The "preferred" default slider position can be set by the users



What slider setting should be used? Auto 3D vs CMR

	CMR mean ± SD	Heart model		p Value	Bias	LOA	r
		Sliders	Mean ± SD				
EDV (ml)	168.5 ± 72.1	70/30	160.2 ± 64.4	0.6	− 14.4	65.5	0.892
		70/40	155.6 ± 65.9	0.46	− 21.8	78.3	0.842
		74/68	156.7 ± 65.8	0.5	− 5.8	62.8	0.910
ESV (ml)	88.5 ± 60.5	70/30	80.8 ± 55.9	0.6	− 9.2	45.8	0.925
		70/40	81.9 ± 54.4	0.64	− 12.9	63.8	0.860
		74/68	90.5 ± 60.1	0.9	9	53.9	0.907
EF %	49.7 ± 16	70/30	54.5 ± 13.8	0.19	2.5	13.2	0.906
		70/40	52.5 ± 13	0.42	1.7	14.7	0.898
		74/68	46.3 ± 12.6	0.31	− 4.9	11.7	0.940

SD standard deviation, *P value t* test *P* value, *LOA* limits of agreement (95% CI), *r* Pearson's correlation coefficient, *HM* heart model, *CMR* cardiac magnetic resonance

Faculty of Medicine
The Chinese University of Hong Kong

Barletta, et al. The International Journal of Cardiovascular Imaging (2018) 34:1205–1213.

What slider setting should be used? Auto 3D vs Manual 3D

	3DE mean ± SD	Heart model		p Value	Bias	LOA	r
		Sliders	Mean ± SD				
EDV (ml)	104.6 ± 48.4	70/30	160.2 ± 64.4	< 0.0001	52.1	59.6	0.875
		70/40	155.6 ± 65.9	< 0.0001	49.1	65.9	0.856
		74/68	156.7 ± 65.8	< 0.0001	53.7	60.7	0.891
ESV (ml)	53.9 ± 42.9	70/30	80.8 ± 55.9	0.003	16.3	28.6	0.929
		70/40	81.9 ± 54.4	0.002	18.3	42.1	0.879
		74/68	90.5 ± 60.1	0.0003	30.9	28.8	0.949
EF %	53.7 ± 15.7	70/30	54.5 ± 13.8	0.7	0.7	13.7	0.888
		70/40	52.5 ± 13	0.6	− 1.5	15.2	0.869
		74/68	46.3 ± 12.6	0.003	− 7.6	13	0.913

SD standard deviation, *P value t* test *P* value, *LOA* limits of agreement (95% CI), *r* Pearson's correlation coefficient, *3DE* 3D echocardiography, *HM* heart model

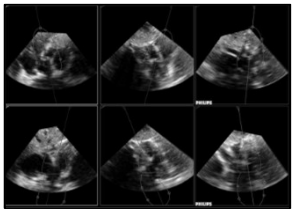
Faculty of Medicine
The Chinese University of Hong Kong

Barletta, et al. The International Journal of Cardiovascular Imaging (2018) 34:1205–1213.

What HM slider settings should be used?

- Somewhat depends on whether the “CMR” accuracy or the “Echo” accuracy is preferred
- Ideally, CMR and echo should give the same values
- CMR is the gold standard
- Echocardiographers are more familiar with echo volume/EF
- No guideline recommendations so far

Faculty of Medicine
The Chinese University of Hong Kong



An example of poor quality image

Impact of image quality on the accuracy of the automated chamber quantification

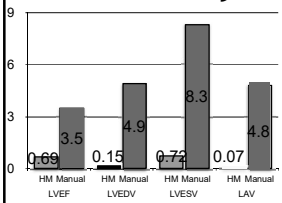
	EDV (mL)		ESV (mL)		EF (%)		LAV (mL)	
Quality	Bias ± SD	*r* value	Bias ± SD	*r* value	Bias ± SD	*r* value	Bias ± SD	*r* value
Good (*n* = 108)	−0.5 ± 9.0	0.99	−0.6 ± 7.0	0.99	0.1 ± 4.4	0.94	1.3 ± 6.5	0.97
Adequate (*n* = 89)	−5.1 ± 13	0.98	−2.0 ± 9.2	0.99	−0.4 ± 5.5	0.93	0.4 ± 8.2	0.97
Poor (*n* = 72)	−2.7 ± 41	0.89	−4.8 ± 32	0.89	0.3 ± 16	0.49	1.8 ± 26	0.81

Comparisons between the automated analysis and 3D-guided biplane measurements in the three image quality groups (*n* = 269).

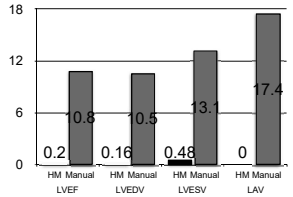
Medvedofsky et al. J Am Soc Echocardiogr. 2017 September ; 30(9): 879–885.

Convergent AI algorithm

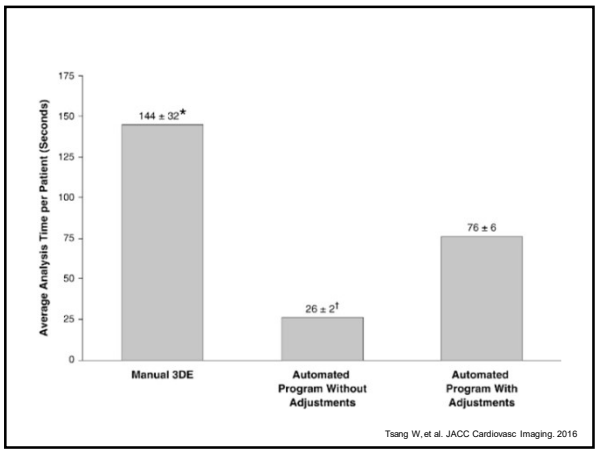
Intra-observer variability



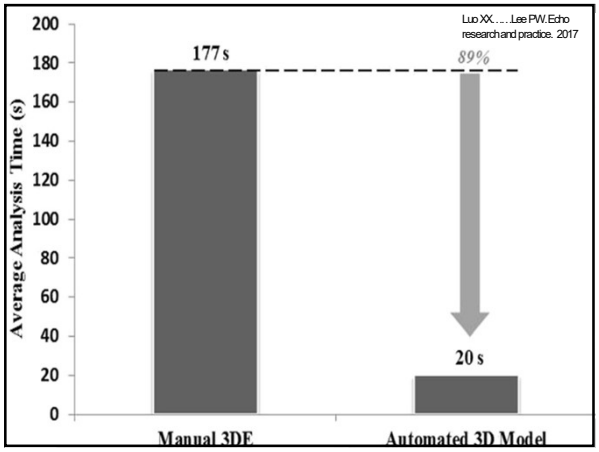
Inter-observer variability



Luo XX …. Lee PW. Echo research and practice. 2017



Tsang W, et al. JACC Cardiovasc Imaging. 2016



Luo XX. . . . Lee PW. Echo research and practice. 2017

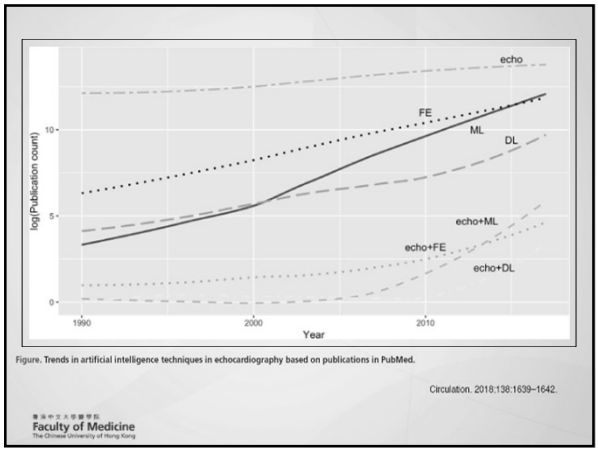


Figure. Trends in artificial intelligence techniques in echocardiography based on publications in PubMed.

Circulation. 2018;138:1639–1642.

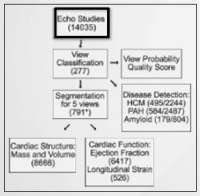
Faculty of Medicine
The Chinese University of Hong Kong

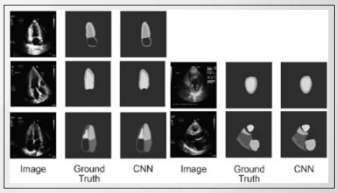
Circulation

ORIGINAL RESEARCH ARTICLE

Fully Automated Echocardiogram Interpretation in Clinical Practice

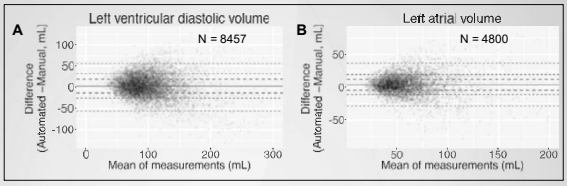
Feasibility and Diagnostic Accuracy

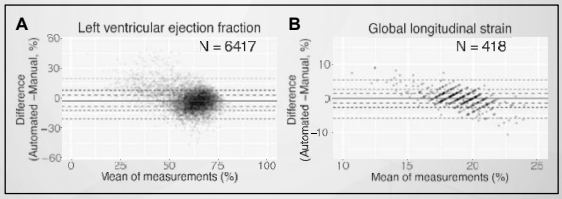




Zhang, et al. Circulation. 2018;138:1623–1635.

Faculty of Medicine
The Chinese University of Hong Kong

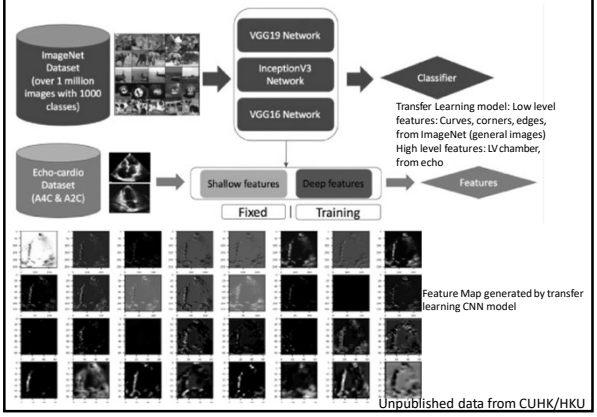




Faculty of Medicine
The Chinese University of Hong Kong

Zhang, et al. Circulation. 2018;138:1623–1635.

AI for LVEF Classification: Transfer Learning Convolution Neural Network



Unpublished data from CUHK/HKU

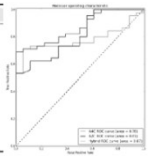
AI for LVEF Classification: Results

- Results on CNN + LSTM + Transfer Learning model
  - AUC: 0.87 for model learning with both A4C and A2C
  - Accuracy: ~90%
  - A4C + A2C: better generalize information, alleviate over-fitting

~4000 echo frames

	A4C	A2C	Hybrid(0.7+0.3)	Hybrid(0.6+0.4)
AUC	0.78	0.81	0.86	0.87
Accuracy	77.78%	80.95%	74.6%	79.37%
Sensitivity	88.89%	33.33%	61.11%	44.44%
Specificity	73.33%	100%	80.00%	93.33%
Positive Likelihood Ratio	3.33	N.A.	3.06	6.67
Negative Likelihood Ratio	0.15	0.67	0.19	0.60
Disease prevalence	28.57%	28.57%	28.57%	28.57%
Positive Predictive Value	57.14%	100.00%	55.00%	72.73%
Negative Predictive Value	94.29%	78.95%	83.72%	80.77%

The performance of current models in LVEF classification



ROC Curve

Unpublished data from CUHK/HKU

Conclusion

- Auto LV volume, EF, strain, and LA volume by echo is now technical feasible thanks to advances in machine learning
- Still underestimate volume compare to MRI
- Source of error: border placement
- Accurate in LVEF
- Reproducibility is excellent because of the convergent algorithm in the latest automation program
- Time-saving
- Advances in deep learning will likely bring automation to various aspects of echo interpretation in the next 5 years

Faculty of Medicine
The Chinese University of Hong Kong