Venue™ is a special kind of ultrasound system. It has been designed for many applications. Among its capabilities is a set of tools specially designed to be useful to clinicians managing patients in medical shock. The designers used a number of academic papers to guide their decision-making.

This white paper summarizes some of the key papers that influenced the design of Venue.

For each of the publications cited in this document, the authors’ conclusions are based on their scientific studies, and must be evaluated by medically-qualified readers. GE does not endorse or support any conclusions or recommendations contained in these publications.
Venue is based on advanced technology, but its inspiration is not in software and fancy processors... it’s in well-established medicine. While many care areas are important for a general purpose ultrasound system, in Venue we focused on tools to help caregivers attending to patients in shock. Our developers read hundreds of papers during the development. These are the top twelve that shaped our thinking. We thought you might like to read along with us.

**The RUSH Exam:**
**Rapid Ultrasound in SHock in the Evaluation of the Critically Ill**
Phillips Perera, MD, RDMS; FACEP, Thomas Mailhot; MD, RDMS; David Riley, MD, MS, RDMS; Diku Mandavia, MD, FACEP, FRCPC. *Emerg Med Clin N Am* 28 2010; 29–56

**Paper synopsis**
The authors discuss the utility of the RUSH protocol to differentiate the four major types of shock: cardiogenic, hypovolemic, obstructive, and distributive.

**How it shaped our design**
This article provided the basis of the Shock Toolkit on Venue. The features that make up the toolkit automate assessments (Cardiac, Lung, Abdomen and Vein) related to the RUSH vernacular of pump, tank and pipes. The resulting Shock Toolkit includes three key tools (Auto B-line, Auto IVC and Auto VTI) intended to help clinicians rapidly determine the source of shock based on methodology described in the RUSH exam.

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Pump

Cardiogenic

Obstructive

Tank

Hypovolemic

Pipes
**Relevance of Lung Ultrasound in the Diagnosis of Acute Respiratory Failure: The BLUE Protocol**

Daniel A. Lichtenstein, MD, FCCP and Gilbert A. Mezière, MD. *CHEST* 2008; 134 : 117 – 125

**Paper synopsis**
This article describes the potential of lung ultrasound in diagnosis of acute respiratory failure. In this observational study, the authors prospectively evaluated 260 acute respiratory failure ICU patients with lung ultrasound and compared the results to the final diagnosis by the ICU team. The authors conclude that lung ultrasound can help the clinician make a rapid diagnosis in patients with acute respiratory failure, thus meeting the priority objective of saving time.

**How it shaped our design**
This article clearly described ultrasound findings and artifacts associated with different lung conditions. It described ultrasound scan techniques, probes, and technology that could impact the quality of lung imaging, and helped guide our thinking in developing lung imaging for Venue.

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**Rapid Ultrasound in Shock (RUSH) Velocity-Time Integral A Proposal to Expand the RUSH Protocol**

Pablo Blanco, MD; Francisco Miralles Aguiar, MD; Michael Blaivas. *J Ultrasound Med* 2015; 34 : 1691 – 1700

**Paper synopsis**
The authors propose expanding the RUSH protocol (evaluating cardiac function, key vascular structures, and likely sources of hypotension) with the addition of an assessment of stroke volume (utilizing velocity-time integral of the flow of the left ventricular outflow tract as a surrogate marker).

**How it shaped our design**
This article provided a robust argument for why and how to incorporate the LVOT VTI into the RUSH exam. This provided motivation to develop an algorithm that would automate steps in obtaining this measurement, thus simplifying and reducing variability.
Point-of-Care Multiorgan Ultrasonography for the Evaluation of Undifferentiated Hypotension in the Emergency Department

G. Volpicelli, A; Lamorte, M; Tullio, L; Cardinale, M; Giraudo, V; Stefanone, E; Boero, P; Nazerian, R; Pozzi, M; F. Frascisco. Intensive Care Med 2013 39: 1290 – 1298

Paper synopsis
The authors prospectively evaluated 108 patients for non-traumatic symptomatic hypotension, and demonstrated good agreement between ultrasound diagnosis and final clinical diagnosis. They concluded that using ultrasound to help identify the cause and guide initial therapy has great potential.

How it shaped our design
This article advanced our understanding of ultrasound patterns found in patients admitted in undifferentiated shock. This helped guide our selection of the first algorithms to develop for the Shock Toolkit- Auto IVC, Auto B-line and Auto VTI.

Inter-Rater Reliability of Quantifying Pleural B-Lines Using Multiple Counting Methods

Kenton L. Anderson MD; J. Matthew Fields, MD; Nova L. Panebianco, MD; Katherine Y. Jenq, MD; Jennifer Marin, MD, MSc; Anthony J. Dean, MD. J Ultrasound Med 2013; 32: 115 – 120

Paper synopsis
In this study the authors included a cohort of emergency department patients with dyspnea whose symptoms were consistent with acutely decompensated heart failure. Three different B-line scoring methods were investigated, and they used inter-reader variability to recommend an approach.

How it shaped our design
This study helped us understand challenges that clinicians face in measuring and counting B-lines, and prompted our thinking of how to develop a simple tool that would help reduce error, speed results, and increase reproducibility.

One key piece of information from this paper that impacted the design was the clear definition of the B-line measurement. This definition was implemented directly into the auto B-line algorithm on the Venue system.
Ultrasound Assessment of Lung Aeration Loss During a Successful Weaning Trial Predicts Postextubation Distress
Alexis Soummer, MD; Sébastien Perbet, MD; Hélène Brisson, MD; Charlotte Arbelot, MD; Jean-Michel Constantin, MD, PhD; Qin Lu, MD, PhD; Jean-Jacques Rouby, MD, PhD; and the Lung UltraSound Study Group. Crit Care Med 2012; Vol. 40, No. 7

Paper synopsis
The authors studied lung ultrasound determination of aeration changes during successful spontaneous breathing trials. They concluded that these may be used to accurately predict postextubation distress.

How it shaped our design
This article described the Lung Tool which is incorporated into our design as a method to document changes in lung aeration over time.
International Evidence-Based Recommendations for Point-of-Care Lung Ultrasound

Paper synopsis
This document reflects the overall results of the first consensus conference on point-of-care lung ultrasound, attended by 28 multidisciplinary experts. The group produced recommendations to guide implementation, development, and standardization of lung ultrasound in relevant settings.

How it shaped our design
These evidence-based recommendations and definitions were used to define B-lines for the algorithm incorporated in the Auto B-line tool, and to guide implementation and development of lung ultrasound imaging on Venue. The recommended terminology and use of ultrasound in lung conditions influenced our training and documentation.

POC
Point of Care
POCUS
Point of Care Ultrasound

EGLS: Echo-guided life support: An algorithmic approach to undifferentiated shock
Jean-Francois Lanctot, Maxime Valois, Yanick Beaulieu
Crit Ultrasound J (2011) 3:123–129

Paper synopsis
The authors present an algorithm to guide management of patients with undifferentiated shock. The basis of the algorithm is simple clinical questions that incorporate ultrasound findings from the lung, heart and inferior vena cava.

How it shaped our design
This paper encouraged us to incorporate a simple approach to the assessment of shock in a way that provides quick access for clinicians, including evaluations of the lung, heart, and inferior vena cava in one application.
Caval Sonography in Shock: A Noninvasive Method for Evaluating Intravascular Volume in Critically Ill Patients
Dina Seif, MD, MBA, RDMS, Thomas Mailhot, MD, RDMS, Phillips Perera, MD, RDMS, Diku Mandavia, MD
Crit Care Med 2012 Vol. 40, No. 7

Paper synopsis
The authors describe caval sonography and how the assessment of the inferior vena cava can provide quick information to help guide resuscitation of patients in shock.
This article defines the IVC Collapsibility Index (also known as the Caval index) for spontaneously breathing patients in assessment of volume status of patients in shock.

How it shaped our design
This provided the background for our development of the Auto IVC tool in the Shock Toolkit on Venue. It helped to define the measurement locations and methods. We used this information to refine the presentation of the results of measurements of the IVC.

IVC
Inferior Vena Cava

The Auto B-line tool highlights and counts B-lines in real-time.
**Bedside Ultrasound in Resuscitation and the Rapid Ultrasound in Shock Protocol**


**Paper synopsis**

This paper introduces the RUSH protocol, and compares it with other resuscitation protocols. This article emphasizes the terms ‘pump’ (heart), ‘tank’ (IVC) and ‘pipes’ (aorta, DVTs) to describe the core areas of assessment.

**How it shaped our design**

This paper presented the need for the automated IVC and VTI algorithms. The paper also provided information about the location and imaging techniques for acquiring the B-lines, which was incorporated into the design of our automated B-line algorithm.

**DVT**

*Deep Venous Thrombus*

**VTI**

*Velocity Time Integral*

**IVC**

*Inferior Vena Cava*

The Auto-IVC tool measures IVC collapsibility. There is a visual representation of the diameter change and it only takes a few respiratory cycles to get the result.
Early Fluid Loading in Acute Respiratory Distress Syndrome with Septic Shock Deteriorates Lung Aeration without Impairing Arterial Oxygenation: A Lung Ultrasound Observational Study

Paper synopsis
Improvements in cardiac preload with fluid loading for septic shock (improving hemodynamics and related oxygenation of vital end organs) is limited by the potential for the extra fluid load. Lung ultrasound can be used to monitor aeration changes which may serve as a safeguard against excessive fluid loading.

How it shaped our design
This paper demonstrated the potential utility of transthoracic lung ultrasound (rapid appearance of B-lines) to track aeration changes. Along with other publications, this prompted us to incorporate a simple lung graphic and tool that allows clinicians to easily evaluate changes in the lung condition across multiple exams. The six region lung segmentation (also used in the BLUE protocol) is one of the lung segmentation graphics incorporated in Venue.

ARDS
Acute Respiratory Distress Syndrome
BLUE
Bedside Lung Ultrasound in Emergency

The Lung Tool keeps track of your segmental lung assessment.
BLUE-Protocol and FALLS-Protocol:
Two Applications of Lung Ultrasound in the Critically Ill

Paper synopsis
This paper provides a summary of the BLUE and FALLS protocols. The BLUE protocol focuses on the assessment of respiratory failure and the FALLS protocol on circulatory failure.

How it shaped our design
This paper was key to the design of the lung and cardiac components of the Shock Toolkit on Venue, and the automation design to help streamline that workflow.

BLUE
Bedside Lung Ultrasound in
Emergency

FALLS
Fluid Administration Limited
by Lung Sonography
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