Potential Chest Compression Injury Mechanism from Mechanical CPR Systems: Comparison of Load-Distributing Band versus Piston-Driven Systems

TECHNICAL REPORT NO. 2

It is widely recognized that patient injury can occur during the delivery of chest compressions.[1] Injuries to the ribs, sternum, liver, and spleen have been reported.[2,3,4,5] A review of the injury-related literature for mechanical CPR technologies (Table 1) reveals a higher rate of injury from piston-driven systems for both the overall rate of injury and the difference from manual compressions.

This difference raises the question as to how the respective mechanisms might influence injury rates. Research specific to CPR-related chest compressions demonstrates that surface pressures less than 5.65 pounds per square inch (psi) result in a minimal risk of injury.[6]

Purpose: This test was designed to understand the injury-generating potential of different mechanical CPR systems by comparing the forces applied to a chest during compressions.

Method: Both piston-driven (LUCAS™ 2) and load-distributing band (AutoPulse®) mechanical CPR systems were applied to a test mannequin in accordance with the manufacturer's recommendations.[7,8] The anatomical characteristics (chest circumference and stiffness) of the mannequin were calibrated to represent the 50th percentile patient.

Data related to the force of compression at the point of maximal depth was obtained and plotted (Figure 1) with a force mat (Tekscan Body Pressure Measurement System, version 5.83C - Boston, MA) that was placed between the mannequin and the contact surface of the respective CPR systems. Compression depths were recorded with a string potentiometer and plotted using a Dewetron Model No. 3200 (Vienna, Austria). The Compression Force was calculated as follows: maximum depth of compression (inches) x chest stiffness (pounds/inch). The length and width of the Contact Surface Area for each system was measured to the nearest 0.25 inch. The pressure delivered to the chest was determined by dividing the Compression Force by the Contact Surface Area for each system.

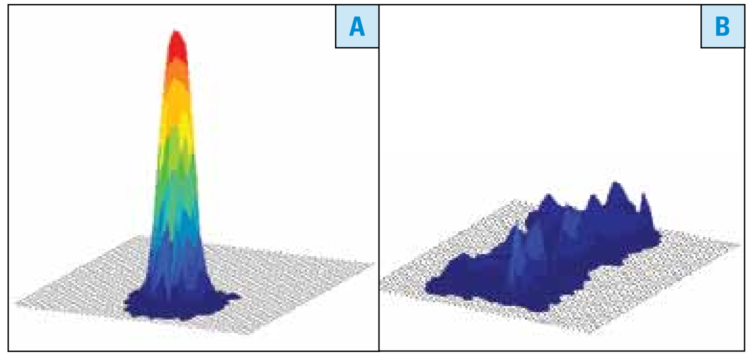

Figure 1 – Force plot data for piston-driven (A) and load-distributing band (B) systems.

Figure 2 – The piston-driven (left) and load-distributing band (right) systems shown applied to the calibrated mannequin.

Table 1 – Reported injury profiles of mechanical CPR technologies*

	N	CPR Injury Rate	Difference from Manual Compressions
Load-Distributing Band			
Paradis[9]	1,020	0.8%	Not Reported
Piston Driven			
Wagner[10]†	18	100%	No Control
Smekal[11]	85	58%	+13%
Menzies[12]	57	63%	+ 31%
Obersladstaetter[13]	16	69%	No Control
Englund[14]	221	65% sternal 93% ribs	+132% sternal + 79% rib

* Excludes superficial injuries such as sternal lacerations, bruising, and abrasions.
† Cath lab experience

Findings: Based on an analysis of the data collected one finds:

- The Compression Force is 2.52 times greater for the load-distributing band system than for the piston-driven system; 280 lbs. versus 111 lbs., respectively. (Table 2)
- The Contact Surface Area is 23 times greater for the load-distributing band system than for the piston-driven system; 100 versus 4.4 inch^2, respectively (Table 2).
- The pressure delivered to the chest at the point of maximum compression is 2.80 psi and 25.45 psi, respectively, for the load-distributing band and piston-driven systems (Figure 3).
  - The pressure delivered by the load-distributing band system is 50% lower than the reported threshold for chest compression injuries.
  - The piston-driven system operates 4.50 times above the reported threshold for safe chest compressions.

Table 2 – Measure forces and contact surfaces

Technology	Compression Force (lbs)	Contact Surface Units (in^2)
Load-Distributing Band	280.0	100.0
Piston-Driven	111.3	4.4

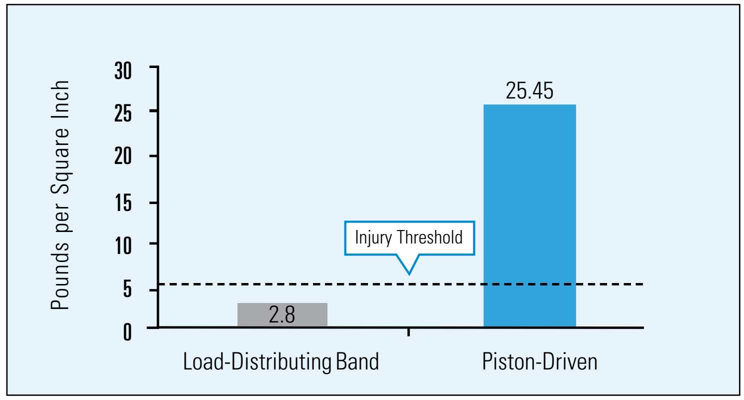

Figure 3 – Pressure delivered to the chest

Conclusion: The smaller contact surface of the piston-driven system (LUCAS 2) results in 1) a pressure delivered to the chest that substantially exceeds the threshold for compression injury, and 2) the larger contact surface of the load-distributing system (AutoPulse) is designed to provide a generous safety margin as the pressure delivered is well below the threshold for chest compression injuries.

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