Leonardo da Vinci first identified the human foot pump in the late 1500s when he stated, “the human foot is a marvel of engineering and a work of art.” It took Gardner and Fox in 1983 to detail the anatomy and physiology of the foot pump as the initiator of the column of blood to return to the heart from the lower extremities. Uhl then dissected 200 cadaveric feet injected with latex to map out the following anatomy of the foot pump in 2010.

Anatomy: The toes and forefoot have a very large, oxygen rich capillary bed that functions to control core body temperature as well as the exchange of oxygen and nutrients to the cells. The veins are organized into the superficial veins, mainly the dorsal and marginal veins, and the deep medial and lateral plantar veins. The deep portion originates in the first metatarsal interspace and forms the much larger lateral plantar vein and the smaller medial plantar veins, which course through the intrinsic muscles and then reunite into the calcaneal confluence of veins in the calcaneal groove. This calcaneal confluence lies at the end of the plantar muscles and can distribute blood to the deep posterior tibial vein as well as the superficial greater saphenous venous system. This is accomplished via the malleolar and navicular perforators. See figure 1.

In figure 1, the pump comprising the deep plantar veins contains three functional parts: A. the front part or suction pole, R. the body of the pump the reservoir, c. the ejection pole.
Because the diameter of the body of the reservoir is twice the diameter of the ejection pole/posterior tibial vein, a bellows effect increasing the velocity of the blood ejected from the pump by four fold. This propels approximately 25-30 cc of blood into the calf and then the calf pumping mechanism produced by contraction of the soleus and gastrocnemius muscles takes over. Once the blood enters into the vena cava a negative pressure from respiration then becomes the most important driving force in the return to the right heart and thus to the lungs to be oxygenated. The fill time in the reservoir is 17-25 seconds, and is subject and health dependent. So the frequency of using an artificial pump should be no less then 20 seconds.

![Diagram of foot and veins](image)

**Figure 2**

Figure 2 A shows that the lateral plantar vein is much larger and carries the most blood. It also demonstrates the perforators that occur from the deep system to the superficial greater saphenous system.

Figure 2.B is the key diagram for Footbeat. This is the representational drawing of the “sweet spot“ in blue where applied pressure empties the venous reservoir. The red area represents the boney prominences. This area will not tolerate intermittent
pressure, and it wouldn’t be effective. The purple is the transitional area. As you can see from this diagram, Footbeat is well within the safe zone, not applying any pressure over the most sensitive areas: a. the metatarsal heads, b. the calcaneal tuberosity, c. the proximal 5th metatarsal head.

The pressures tolerated over a long period of time on the sole of the foot are not known. But we generate over 300-500 pounds/cm\(^2\) over the calcaneal prominence on heel strike when walking. The users selected pressure settings on the AVI device by Kendall, is 130mm Hg and 180mm Hg. These pressures have been used for 30 years with no known complications. Footbeat pressures at 65 N or 230 mm Hg of force. This force has been tolerated well in the clinical trials which have involved Footbeat prototypes.