A MEMS Drug Delivery Device for the Prevention of Hemorrhagic Shock

H.L. Ho Duc, M.J. Cima
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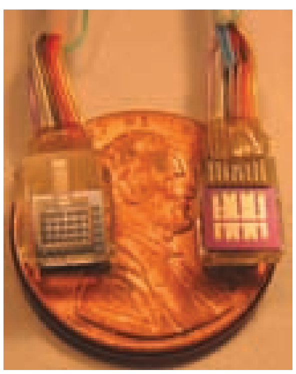
Hemorrhagic shock is the number one cause of preventable death on today's battlefield [1]. It is a hypotensive state of deficient organ perfusion caused by blood loss from wounds of the extremities or internal injuries. Hemorrhagic shock is normally treated by hemorrhage control, fluid replacement, and the injection of vasoconstrictors. Battlefield conditions, however, can prevent the timely administration of these measures. Hemostatic dressings developed for battlefield application are useful in controlling open wound hemorrhage but cannot stop internal bleeding or avert shock if too much blood has been lost [1]. Arginine vasopressin is a vasoconstrictor that causes peripheral and abdominal arteries to constrict, shunting blood to the vital organs in case of hemorrhage [2]. It improved survival by restoring blood pressure in pre-clinical experiments and clinical case studies of hemorrhagic shock when treatment was not immediately available [3-7]. This property makes it a perfect candidate for battlefield injection to keep wounded soldiers alive until they can be properly treated. Self-injection may not always be possible, however, due to the nature of these traumas.

We are currently developing an implantable drug delivery microelectromechanical system (MEMS) to deliver vasopressin to wounded soldiers on the battlefield. This device consists of a silicon substrate in which pyramidal wells are etched using common MEMS processing techniques. The wells are capped by metallic membranes and the chip is hermetically bonded to a Pyrex macroreservoir (Figure 1). The macroreservoir can be injected with 25 μL of a vasopressin solution to be released on demand. Applying an electric pulse through a metallic membrane melts it by resistive heating, exposing the macroreservoir to the environment. We also observed the formation of multiple thermal bubbles inside the macroreservoir, which enabled rapid delivery of the solution. We are redesigning the device to better control this mechanism. Future challenges include insuring long-term hermeticity and wireless activation of the device.



◄ Figure 1: Picture of the MEMS device showing the Pyrex macroreservoir (left) bonded to the silicon chip (right). The metallic layer on the silicon chip controls the opening of micro-wells allowing vasopressin out of the macroreservoir.

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