Complete prevention of blood loss by self-sealing hemostatic needles

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Syringe injections are often required in many clinical situations for administering drugs, collecting blood samples, and providing fluid therapy. Thus, the use of self–sealing hemostatic needles may help prevent complications associated with bleeding in clinical settings, especially for diabetic patients who experience delayed hemostasis and for biopsy procedures, thereby preventing profuse bleeding. Furthermore, based on the findings of research on the self–sealing mechanism of mussel–inspired polymers, a variety of therapeutic/diagnostic biomedical devices with hemostatic capabilities, such as endoscopes and catheters, may be developed in the future.

● Bleeding unavoidably accompanies injections when a conventional needle penetrates tissue. Although controlled bleeding does not harm healthy individuals, uncontrolled bleeding may cause serious complications for those who suffer from hemophilia, coagulopathy, or diabetes or have been exposed to infectious diseases. This study shows how a hemostatic hypodermic needle coated with a partially cross–linked mussel–inspired polymer that undergoes a solid–to–gel phase transition in situ can seal punctured tissues.

● A syringe is one of the most common medical tools for drug administration, fluid therapy, blood sample collection, and general surgery, including plastic surgery. For normal patients, bleeding from punctured tissue following an injection causes little to no harm. However, for patients with diabetes, advanced cancer, or bleeding disorders, such as hemophilia, the bleeding often results in serious problems related to delayed hemostasis and its side effects and blood–borne viral infections. Thus, we are motivated to develop a self–sealing hemostatic needle using mussel–inspired catecholamine polymers.

● To create such a self–sealing hemostatic needle, the mussel–inspired catecholamine polymer catechol–tethered chitosan (CHI–C) was used to coat the surfaces of commercial needles (Figure 1a). One drop of CHI–C solution was gently placed on the needle surface and allowed to evaporate for several hours, generating a polymeric microfilm (Figure 1b). The critical variable of in vivo hemostasis is the degree of catechol/amine oxidative crosslinking, which was controlled in the pre–incubation step of the polymer solution, before the coating process. Similar to commercial hemostatic agents, such as fibrin glue, the CHI–C microfilm has strong mechanical properties that make it capable of easily penetrating from skin tissue to blood vessels. The microfilm of the pre–incubated CHI–C is transformed into a tissue–adhesive hydrogel upon contact with blood, exhibiting self–sealing properties on the punctured tissue. This is an unprecedented phase transition process in the development of hemostatic needles. The self–sealing property is effective for both normal and impaired bleeding animal models, as it does not depend on native hemostatic capability. In the rabbit ear vein bleeding model, the use of commercial needles showed 200 μL of blood loss. In contrast, the use of hemostatic needles completely prevented blood loss (Figure 1c, left). Furthermore, in the hemophilic mouse bleeding model, all mice were dead at 7 minutes after intravenous injections using commercial needles; however, all mice injected with hemostatic needles were still alive at that time (Figure 1c, right).

The fixed gels on the punctured tissue were not circulated in the blood stream, and no hematotoxicity was observed. Thus, it is expected that the hemostatic needles will be approved for clinical trials.

● These results for the hemostatic needles and their self–sealing mechanism can be useful for the development of a variety of minimally invasive medical devices with hemostatic capabilities for patients with bleeding disorders and cancers.

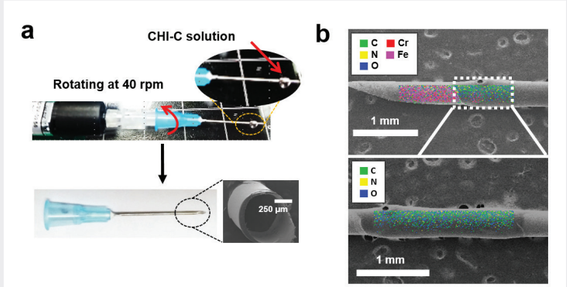

Figure 1. (a) Preparation of the hemostatic needles (b) Chemical analysis of the polymeric coating on the surface of the needles (c) In vivo hemostatic effect of rabbit ear vein bleeding (left) and hemophilia mouse vein bleeding models (right)

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