JET INJECTORS = JET INFECTORS

How Do Jet Injectors Work?
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(Ismach, 1978)
Jet injectors administer injections within three phases.

1. The Peak Pressure Phase
2. The Delivery Phase
3. The Drop-off Phase
1. The Peak Pressure Phase

The Peak Pressure Phase requires optimal pressure for penetrating the skin and for carrying-out the entire injection process. The breadth of this phase can be better understood when broken into smaller phases.

   a. Actuation of the energy source- The peak pressure phase starts when the energy source is actuated, subsequently triggering a piston or plunger, which causes an...

   b. Instantaneous increase in pressure onto the liquid medicament within the drug reservoir. The peak pressures within the drug reservoir range from 14-35 MPa, or ~2,000 to 5,000 psi (Schramm & Mitragotri, 2002). This amount of pressure is needed for the jet stream to penetrate skin and to carry-out the required pressures for the rest of the phases.
c. Liquid medicament starts to eject through nozzle orifice. The liquid medicament is ejected through the nozzle at a velocity ranging from 100 to 200 meters per second. Once the liquid medicament is expelled from the jet injector it creates a jet stream. Initially the jet stream is comparable to the size of the nozzle orifice, which would be roughly the thickness of 100 micrometers. This would be slightly thicker than the size of a single-strand of hair (70 micrometers) but less than one-fourth the size of a 24-gauge needle (460 micrometers) (Dyer, 2003). The further the jet stream travels away from the nozzle the greater the diameter of the spray increases creating a cone shape.

d. The jet stream penetrates the skin starting the creation of hole formation. Penetration of the skin, also referred to as impinging the skin, is achieved through a combination of eroding and fracturing of the skin and tissue (Baxter & Mitragotri, 2005).
Shergold, Fleck & King (2006) reported, “experiments reveal that a high speed liquid jet penetrates a soft solid by the formation and opening of a planar crack.” The planar crack formed by jet injection is no different in characteristic than those formed from a sharp-tipped object.

Fig. 6. Penetration of (a) human skin, and (b) B452 silicone rubber by a \( 0.34 \) mm high-speed liquid jet results in a planar crack.
e. Increase in the depth of the hole formation. The dimensions of the hole are established within the first few hundred microseconds of an injection (Baxter and Mitragotri, 2005). As the depth of the hole increases the velocity of the jet stream decreases. This leads to a weak jet stream that no longer deepens the hole.

f. Stagnation of the jet stream at the end of the hole completes this phase.

Within the first phase the jet stream is unidirectional meaning it flows in one direction—into the skin.
2. The Delivery Phase

- The Delivery Phase refers to the delivering of the remaining liquid medicament but with less pressure and velocity.

- Whereas phase 1 is for the creation of hole formation, phase 2 is for the delivery of medicine.

- This phase has also been referred to as the Dispersion Phase, due to the liquid medicament within the newly constructed hole dispersing into surrounding tissue, cells, and muscle. The absorption of the liquid medicament slows down the pressure of the jet stream.

- During this phase the jet dispersion is multidirectional.
2. The Delivery Phase cont’d

- Kale and Momin (2014) found, “If the volumetric rate of hole formation is less than the volumetric rate of [the] jet impinging the skin, then some of the liquid splashes back towards the injector.”

- Since the velocity being exerted is on a continuous decline until being completely exhausted, the volumetric rate of hole formation would be less than the volumetric rate of the jet impinging the skin, therefore liquid splashing back towards the injector would be an expected phenomena.

- In quoting Voelker (1999) who paraphrased it so simply, “Jet injection builds pressure in the skin that is greater than the pressure in the injector, causing a small backflow.”
3. The Drop-off Phase

- The Drop-off Phase refers to the conclusion of the injection.
- Following an injection the skin can redden, bruise, or develop a wheal.
- A wheal is a bulge under the surface of the skin caused by the recent deposit of injected fluid. Wheals will eventually go away as the fluid is absorbed into the deeper tissue layers. The size of the wheal depends upon the volume of liquid medicament being injected (Mitragotri, 2006).
This graph shows the stages of jet injection in relation to the expending of pressure and the lapse of time.

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