snow science

This shot of Berthoud Pass was taken just minutes before an avalanche occurred on the Stanley path, just out of frame to looker's right. The slide caught a couple of cars and created more headline news than anyone cared.

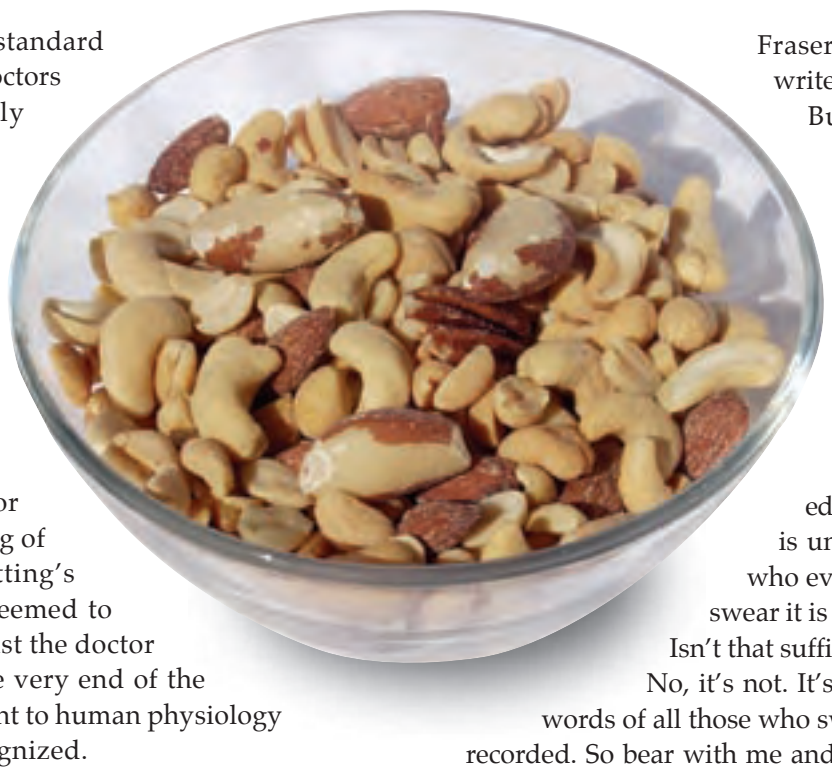
Bloodletting, Water, Brazil Nuts, Swimming, and Dying in Avalanches

Story and photos by Dale Atkins

You probably never wondered why or how bloodletting, Brazil Nuts, and swimming have anything to do with dying in avalanches. If, however, you spend any time in avalanche country, you may want to keep reading because there is a connection. Basically, bloodletting, like swimming in an avalanche, seems like the logical thing to do, but the premise on which both are based is wrong. While avalanches may flow like a river, an avalanche is not a liquid. Because avalanches are not a liquid, Brazil Nuts, not swimming, better explain how and why one gets to the surface. For those who couldn't get to the surface their burial was more about bad luck then actions, and worse, swimming leads to dying. Curious to learn more? Let's start with bloodletting.

BLOODLETTING

For two millennia, bloodletting was a standard and very popular treatment provided by doctors (and others, like barbers) to treat nearly all physical and psychological ailments. From long before Hippocrates to just over one hundred years ago, bloodletting, or bleeding out a pint or two (or more) of blood seemed like the logical way to free the body of bad things and to restore health. The reason bloodletting endured such a long run of popularity was that it seemed to work – but for all the wrong reasons. Because bloodletting seemed to work, early doctors kept at the practice for thousands of years. With no understanding of physiology, the explanation for bloodletting's success was simple. Bloodletting either seemed to help or it didn't, and if it didn't help at least the doctor could say he had tried. It wasn't until the very end of the 19th century when physicians gained insight to human physiology that the recklessness of bleeding was recognized.



WATER AND AVALANCHES

Just like bloodletting seemed like the logical thing to do, swimming seems like the logical thing to do when caught in an avalanche. Fortunately, modern medicine exposed the folly of bloodletting when the premise (bad things in the body can be released by bleeding) was learned to be faulty. I hope to do the same by explaining how the premise for swimming in an avalanche is faulty. To do this I will discuss nuts, but first, we have to rethink the analogy of avalanches and water.

How often have you heard or described an avalanche as being like a river? Flowing water has been used as a metaphor to describe avalanche motion for nearly 100 years. When in water, what's the most natural thing to do? Swim! When it comes to the mention of swimming – when caught – in an avalanche the record goes back well over 100 years.

The first mention of swimming is found in Colin Fraser's seminal classic *The Avalanche Enigma*, where he cites a Swiss man, Philip Gosset, who swam in an avalanche in 1864. Of the experience, Gosset said, "I was aware of the avalanche… to prevent myself sinking…I made use of my arms…as when swimming." Ever since, the accident record is filled with people attributing their survival to swimming. In fact, 40 years ago, Fraser wrote "…make strong swimming movements with arms and legs in an effort to stay on the surface."

Fraser was probably not the first English-language writer to order those caught in an avalanche to swim. But ever since, every avalanche instructor in North America has commanded, "Swim!" Even Hollywood presented the advice in Robert Redford's 1972 mountainman-epic *Jeremiah Johnson*. At the end of the movie Redford's Johnson meets back up with his mentor old Bear Claw Chris Lapp (played by Will Geer) who tells Johnson in a slow, matter-of-fact tone that an "Avalanche took the cabin. Lost my mule. We swum out of it."

To swim has become an axiom of avalanche educators everywhere. The problem is that swimming is unproven. Unproven? What about all the victims who every winter said they swam in the avalanche and swear it is the reason they got to (or stayed on) the surface? Isn't that sufficient proof, you ask?

No, it's not. It's simply a very biased sample of survivors. The words of all those who swam but ended up buried and killed were never recorded. So bear with me and keep in mind that, while I can't present sound statistical conclusions that swimming does not work, there is no statistical evidence or even science that suggests swimming works.

The physics of swimming to the surface of an avalanche do not make sense or even compute. The reason a human body floats in water is because our bodies are about the same specific weight (think density) of water. Some people (and you know who you are) are better floaters than others, but everyone with a chest full of air will float. This works in water, but in an avalanche the specific weight of the moving snow may be only one-third the specific weight of water, and snow can be a whole lot less. It is not buoyancy that causes us to float to the surface. Swiss avalanche researcher Martin Kern found that even the avalanche airbag system that adds another 150 liters of volume to a body "is not sufficient to keep a skier on the surface of a flowing avalanche." So if hydrostatic buoyancy doesn't keep one on the surface, what does?

BRAZIL NUTS

Before getting into nuts there is some good news and bad news about getting caught in an avalanche that should be reviewed. First, the good news: total burials don't happen very often. Data collected by the Colorado Avalanche Information

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BRAZIL NUTS

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Center shows that in Colorado from 1970–2005 a total of 1748 people were reported caught in avalanches and 309 people or 18% were buried. But before saying this number is significant, keep in mind the bias in reporting of serious – buried victims – accidents. While the actual number of people caught is unknown (reported + unreported), it is reasonable to estimate that perhaps two times (or more) as many people were caught in avalanches than reported. Assuming that most burials do get reported (a reasonable assumption) this means the actual burial rate might be only one-half (or less) the reported burial rate. The bottom line is simple: few victims get buried.

The bad news is pretty sobering: once buried, about half the victims died. Since 1970 a total of 170 victims in Colorado were killed, and nearly every one was buried. Certainly getting buried is bad news, but why do most people not get buried? The answer can be explained with a bowl of mixed nuts.

While avalanches move in a fluid-like state, avalanches are not liquids and are certainly not water. Avalanches are gravitational granular flows, a phenomenon that has both fluid and solid aspects. In granular flows the biggest particles end up on the surface. Granular flows are found all around in nature, industry, and home. Besides avalanches, other examples of granular flows include river sedimentation, dune formation, soil liquifaction, pharmaceuticals, animal feed, coal, breakfast cereals, and mixed nuts.

Under the influence of gravity, smaller particles settle to the bottom and force larger particles to the top where they tend to stay. This process, known as the Brazil-nut effect, is formally called inverse grading (or segregation). Rather than mixing, granular flows de-mix, as smaller particles settle to the bottom and the flow becomes laminar. Shake a bowl of mixed nuts and the large nuts (like Brazil nuts) rise to the top. You may have noticed the same effect in your morning cereal box. The crumbs settle to the bottom and the large pieces rise to the top. The same thing happens in an avalanche. Little trees get buried; big trees tend to stay on the surface. Snowmobiles tend to stay on the surface far more often than their riders. Relative to slab fragments, a person tends to be a pretty big "nut" and is forced to the top of the flow. Becoming a big nut, so to speak, is why avalanche airbags, and exclusively the German ABS system, has been shown to significantly increase the chances of survival by helping prevent burial. Inverse grading Brazil-nut effect explains why relatively few people get buried in avalanches and why people swept under can reach the surface.

Once the avalanche starts down the mountain the particles tend to segregate quickly and flow in parallel layers. As chaotic as they look, avalanches actually tend to present pretty laminar flows. If you doubt this, check out the parallel striations in the snow cover in tracks and runout zones after an avalanche has plowed through the snow cover. Certainly, terrain irregularities can upset the smooth flow and cause some mixing. This is why avalanche victims describe the flow as like that of a river or waves. In some long-running avalanches, victims have described what seems like a wild swim down a raging river. They start on the surface but find themselves dragged down, but are able to struggle or "swim" back up to the surface. Some victims describe several cycles of being pulled down and fighting back to the surface. This up-down motion can easily be explained in granular flows. When the avalanche flows over a terrain feature (steeper slope or surface irregularities), the flow can become turbulent (mixing) causing the victim to be pushed down. As the flow smoothes out, it is the particles segregating (de-mixing) that force the person back to surface.

For nearly 150 years people have declared how swimming helped them not get buried, but armed with a modern understanding of avalanche flow a logical deduction bears out that getting to and staying on the surface had nothing to do with swimming. Like bloodletting, the logic of swimming seems sound, but the premise is wrong. It's not swimming or buoyancy (floating) that gets a body to the surface, it is the physics of the flow (particle size) forcing one to the surface.

BAD LUCK

While the motion of an avalanche tends to force people to the surface, it is simply bad luck that determines who gets buried (terrain traps not included). In some avalanche accidents, two people caught very close together – even as close as a few meters apart – have ended up in vastly different circumstances when the avalanche stops.

One person – lucky – stops on the surface, buried just to the ankles, while their friend – unlucky – ends up buried under a meter of snow. They both took the same ride and swam (or sometimes neither could swim because the avalanche was too powerful), but one gets buried and one is on the surface. To understand what happened to the two victims we need to look again at avalanche movement.

When an avalanche *slows* (but before it stops), the snow fragments interlock, resulting in a change in state from a fluid-like flow to that of a sliding block (everything moves as a single unit or block). In large avalanches this sliding block can travel long distances. When the flow becomes a sliding block a person inside the flow is immobilized and if below the surface, stays buried. The person at the surface stays at the surface. It is all a matter of luck whether the victim is on the surface or engulfed in the flow when the debris becomes a sliding block. The victim trapped beneath the surface in the sliding block suffers bad luck and stays trapped in the sliding block as the avalanche comes to a stop.

AVALANCHES SLOWING DOWN — IT'S TOO LATE

In the paragraph above I highlighted the word *slows*. When considering people caught in avalanches we need to rethink our use of words like slows and decelerates. How many times have your heard and read something like the following: "When the avalanche slows down (decelerates or comes to a stop) get your hands in front of your face to create an air pocket or try to extend a hand to the surface." Reading and hearing people talk about what to do when avalanches slow down makes one think it is very possible and reasonable to create an air pocket. However, talk to buried avalanche survivors, and you hear a very different story.

"You've got to fight. Fight like hell!"

—Tom Kimbrough, *Winning the Avalanche Game*

How many avalanche educators have repeated these words? Indeed, how many students have reiterated them? Tom's segment on what to do if you're caught in an avalanche sticks with most everyone who has seen it. I believe it, as do many others. I first read Dale Atkins' article as a reprint from the *Boulder Camera*. I found it intriguing yet disturbing at the same time. I had the opportunity to read the draft of his article for *The Avalanche Review* and feel I better understand his argument. I won't argue with inverse grading, laminar flow, or turbulent suspension versus gliding flow. I am not an engineer, but Dale presents a consistent picture of avalanche mechanics with what I understand and have read. BUT I feel the take-home message from his article could use some elaboration.

In my time as a backcountry skier, outdoor educator, and heli-ski guide I have ski triggered a lot of avalanches…scores even. I have been caught by three of those avalanches and have had several friends/colleagues caught in my view as well. Without going into a case-by-case analysis, I can say that clawing into the bed surface, pushing blocks around yourself, log-rolling out of moving debris, and generally *fighting like hell* does work to get people out of moving debris, or at least to the top of it. I agree that swimming may not be the mechanism that allows people to surface in a moving avalanche, but doing everything you can to escape the flow seems like better advice than solely focusing on your airway. I would hate to leave it to luck whether I end up as a Brazil nut close to surface or as a hazel nut at the bottom of the debris pile.

Dale has dug up a lot of avalanche victims and his observations carry a lot of weight with me. I think the missing parts of the equation are the many who were caught, but not fully buried. Part of their luck may have been inverse grading, but for a great many avalanche practitioners, it is because they fought with every ounce of their strength to get out of the avalanche, and they did (even in some larger avalanches – D3s). They aren't part of a data set, and like me, they hope never to be part of one.

I think Dale's article brings up good points, and I will be less likely to tell my students and clients to swim in an avalanche. Air pockets are critically important, and knowing when to get one hand in front of your face and the other up out of the snowpack is an impossible concept to teach. You can bet though that I'm going to tell them to heed Tom's words. Many of my friends have done just that and they are still here to argue their case over a few beers…and a bowl full of mixed nuts.

Respectfully,
Don Sharaf

Paramedic Kevin Kelble, long-time Copper Mountain patroller, waves in the Flight For Life air ambulance during an avi-dog drill.

Survivors seldom say their avalanche slowed down and that they had time to get their hands in front of their face. Usually survivors use words like *abruptly*, *suddenly*, and *quickly* to describe how the avalanche *just stopped*. These survivors generally add to their narrative that they either had *no time*, *no chance*, or was *not possible* to get their hands to their face. There are two simple reasons why they couldn't do it.

First, avalanches that catch people (typically falling between 100-200 vertical meters) tend to stop rather abruptly, perhaps in just a second or two. In these cases there simply isn't enough time to get the hands in front of the face. The second reason has to do with the change in state from a fluidized flow to a sliding block described earlier. This transition happens abruptly once a certain velocity threshold is reached. An avalanche may still be traveling at a relatively speedy rate when it transitions to a sliding block – immobilizing the person – before the avalanche starts to noticeably decelerate. If you're busy swimming when the flow suddenly and unexpectedly transitions to a sliding block, your hands will remain stuck far away from your face, and this is why swimming leads to dying.

Certainly getting buried is bad news, but why do most people not get buried? The secret can be found in a bowl of mixed nuts.

SWIMMING LEADS TO DYING

It's pretty simple why swimming is so harmful. Swimming keep the hands away from the face, and a crisis occurs before the avalanche evens stop. When the slab fragments interlock, the ability to get hands in front of one's face is lost even though the avalanche is still moving. Once the snow stops, it is nearly impossible to move the hands to the face to create the essential air pocket. Without an air pocket the consequences of a burial are too often fatal, unless uncovered in minutes. Having dug out well over a score of victims (all deceased) and having seen pictures of scores more, a common condition was that the hands and arms were nowhere near the face. Based on interviews, many burial survivors – nearly all – got their hands in front of their face early and created an airspace. (In addition, most also had fast-acting friends.)

WHAT SHOULD YOU DO?

If you have gotten this far, it should be pretty clear I don't favor swimming. In Europe many avalanche educators and guides for decades have suggested trying to "log roll" out of an avalanche. While this may work in small avalanches, it will not work in larger, faster avalanches. So if you're wondering what to do if caught, my answer is pretty simple. Once knocked off your feet you should get your hands up to your face. Of course, if you can grab on to some fixed object, do. (Each second hanging on means that much snow goes past and can't bury you.) But don't wait to get your hands in front of your face. In shorter running avalanches, stopping occurs quickly. In longer and larger avalanches there might only be a few seconds where you have control over your actions before the slide is moving too fast, and suddenly you are tumbling and rag-dolling in an out-of-control ride. Keeping your hands in front of your face is always much easier said than done however. Halsted Morris – former long-time education coordinator for the Colorado Avalanche Information Center – suggests a simple technique that could keep the hands near the face. Halsted suggests reaching across the face and grabbing a jacket collar or the pack strap where it crosses the shoulder. You may not have your hands in front of your face, but you can use the crook of your elbow to create an air pocket. While hanging on to a collar or pack strap does not place your hands immediately in front of your face, it is more apt to maintain airspace in a tumbling ride.

A FEW FINAL WORDS

It is my opinion that swimming leads to dying, and I hope this essay convinced you of swimming's potentially harmful outcome. Whether you are convinced or unconvinced about swimming (or of my argument), I hope you will question the long-held belief about swimming, and I hope others will research this issue. Telling people not to swim is a major departure from how we all were trained and how we may train future generations of snow enthusiasts. While we ponder what to teach in the future, we also need to look at what we have missed from the past. The concepts about avalanche motion – granular flows, laminar flow, inverse grading, deceleration rates, inter-locking fragments, sliding blocks – are not new. Quite the contrary, these principles have been around and are well accepted to describe avalanches by the science and engineering communities for years. Unfortunately these principles, their meanings, and their implications have not been communicated to field practitioners and sports enthusiasts.

Some of you may remain unconvinced about not swimming, especially in the absence of statistical confirmation. Skeptics must also remember there is also no statistical confirmation about the efficacy of swimming. Sure, there is a vast record of first-hand reports that swimming saved lives; however, this outcome does not make sense with our modern understanding of avalanches. Perhaps the more important – but seemingly forgotten – record is the long list of dead avalanche victims who knew to swim and who relied on swimming to save their lives. Tragically, swimming didn't work for them and their families.

Dale Atkins is the US representative to IKAR, the International Commission on Alpine Rescue. After many years working for the CAIC, he now consults for RECCO AB. He is writing another volume of ***The Snowy Torrents, 1987 to 2005****, which is due out in 2008, to add to the now out-of-print set of classic volumes.*