ARROWS FOR ELK HUNTING (by Adrian Farmer, Bruce Baker, and Ed Ashby)

Archery hunters face a bewildering array of equipment choices advertised to be more accurate, more deadly, lighter, faster, etc. Despite these apparent advances in technology, more than 20 scientific studies of deer and elk show that crippling rates are high, with about one animal wounded and lost for each one found and tagged. As ethical hunters we must do better, but how?

The conventional advice offered in archery blogs and publications is to: 1) use any broadhead as long as it is razor-sharp, and 2) practice in order to insure good shot placement. Obviously, these are important and necessary preparations, but they are often insufficient to get the job done. Even with razor-sharp broadheads and good shot placement, studies show that a major reason for crippling losses is poor arrow penetration, which occurs even with bows of heavy draw weights while hunting big game animals the size of elk or smaller. How do we avoid such failures?

Excellent guidance can be found in the results of more than 25 years of field research into arrow lethality (*Ashby Library*). The original “Natal Study”, conducted under the auspices of the Natal Parks Board of South Africa, provided information from 154 shots on impala, nyala and warthogs, animals roughly the size of small whitetails, mule deer, and feral hogs. Over the next 25 years, studies examined over 3300 shots into freshly downed test animals of elk-sized and larger species, primarily to refine data on arrow penetration. Concurrently, data were collected from 627 big game animals taken during actual bowhunting, using the arrow setups suggested by previous studies. Studies were conducted using all bow types (traditional, compound, and crossbow) to focus on factors most important to arrow performance regardless of bow type. Collectively, there are data from more than 4000 shots taken on live or freshly-killed animals, by far the largest sample of its kind.

Results show that inadequate penetration is the number one reason that arrows fail to be lethal. In almost all cases, penetration failure is due to a structural breakdown of the broadhead or other parts of the arrow system when encountering rib bones. An arrow’s penetration potential is determined by its “transfer efficiency”, or how effectively the arrow applies its force to the tissues. There are a number of factors that influence the arrow’s penetration potential. These factors are interrelated and synergistic, so that the effect of improving multiple factors is greater than the sum of individual percentage increases. You can enhance terminal performance adopting any single penetration factor, but the more factors you add, the better the arrow’s penetration.

Our purpose in this article is to summarize the important factors affecting arrow penetration to help you begin building a more effective elk hunting arrow. Links to specific articles in the *Ashby library* are included to provide more information on specific topics. The factors to consider are:

1. Structural integrity. To achieve effective penetration and a lethal hit, the broadhead and the shaft must remain undamaged regardless of tissues encountered or angle of impact. The ideal broadhead has sufficient thickness and quality of steel such that it neither bends nor breaks on bone impact (but tends to break before taking a bend), and a Rockwell hardness between 49 and 55 (*Arrow Lethality 3; Part3, 2005 Update*).

 The shaft must remain undamaged. Shaft failures usually occur immediately behind the broadhead taper. Using steel broadhead adaptors and/or steel/brass inserts increases strength at this weak point (these can also increase FOC– see 3 below). Longer inserts, extending farther into the shaft, provide even more strength. If using wood shafts, choose a wood that provides high strength and integrity either as primary shafting or as a footing (*Part 4, 2005 Update; 2007 Update, TG Part 2*).

1. Arrow flight. Hand-in-hand with arrow integrity is the quality of arrow flight. Poor arrow flight places additional stress on arrow components at impact and during penetration. Poor arrow flight can occur for a number of reasons, and may become a problem as you experiment with different shaft/broadhead choices in an attempt to build a better hunting arrow. This can be a tedious process, but stick with it until you get it right. When a structurally sound, perfectly flying arrow hits the elk, then other design factors come into play.
2. Arrow forward-of-center (FOC). Substantial penetration gain occurs with arrows having an FOC greater than 19 %. Extreme FOC arrows (19-30% FOC) show a penetration increase of 20 % for arrows of 800 grains, and 50 % for arrows of 650 grains. Extreme FOC is most easily achievable with carbon shafts because of difficulty maintaining perfect arrow flight with other materials. (EFOC has been obtained with aluminum and footed wood shafts but it requires extraordinary effort to do so.)(*Part 2, 2005 Update; Prologue, 2007 Updates, Understanding FOC; Part 3, 2007 Updates; Part 4, 2007 Updates*).
3. Broadhead mechanical advantage (MA). Long, narrow broadheads have a penetration advantage over shorter, wider heads due to their higher mechanical advantage, a measure of the broadhead’s ability to do useful work (e.g., penetrate tissue) with a given force of impact. For a given broadhead length and blade width, fewer blades creates higher MA. Thus, 2-blade heads tend to penetrate better than 3 blade and 4-blade heads with similar blade design (*Arrow Lethality 4*).
4. Shaft and ferrule diameter. A shaft diameter greater than that of the broadhead’s ferrule averages a 30 percent loss in penetration through fresh, real animal tissues compared to a shaft diameter equaling the broadhead’s ferrule. Penetration was increased by 10 percent when the shaft diameter was less than that of the ferrule; thus, it’s best to select a shaft that has a smaller diameter than the back of your chosen broadhead.

1. Arrow mass. Increasing arrow mass results in increased penetration and, despite what you may have heard, momentum is more important than kinetic energy in predicting penetration. In other words, slow and heavy is better than fast and light when it comes to penetration*.* The penetration advantage of increasing arrow mass is less important when only soft tissues are encountered. When bone is encountered, however, mass becomes a much more important factor (*Momentum, Kinetic Energy, and Arrow Penetration; Part 5, 2005 Study Update*). Data show that there is a persistent, repeatable threshold value of arrow mass at which the *frequency* of *heavy bone* penetration suddenly increases. This “heavy bone threshold”, which occurs at about 650 grains, is more dependent on arrow mass than the force of impact. Overall penetration, *after breaching heavy bone,* is also more closely related to arrow momentum (*Part 6, 2005 Update*).
2. Broadhead edge finish**.** Broadhead edges that are honed and stropped to a razor-sharp edge have 26% better penetration than a smooth, filed edge, and 46 % better penetration than a “Hill type” serrated edge. The stropped edge also cuts in such a manner that it minimizes clotting (*Part 1, 2004 Update; Clotting cascade*)*.*
3. Shaft profile. In fresh tissues, tapered shafts out-penetrate parallel and barrel-tapered shafts by 8 to 15 percent, respectively*.* Whether this penetration gain is an effect of the slight FOC increase (tapered arrows have a naturally higher FOC), or other factors, is unclear. The taper may constantly lower shaft drag the deeper it penetrates. The progressively increasing cavity created between shaft and tissues may facilitate the flow of shaft-lubricating blood, reducing friction (*Part 2, 2004 Update*).
4. Broadhead/arrow silhouette**.** The broadhead and arrow should be as smooth and slick as possible. The broadhead ferrule transition should be smooth, without bumps or irregularities that might catch on bone, hide, or other tissues and reduce penetration. Teflon coated broadheads shows a penetration gain in *soft and extremely fibrous tissues*, although it makes little difference in bone penetration. Slick shaft finishes reduce friction between shaft and tissues, retaining more force for penetration. Some finishes become slicker in the presence of blood, and the lubricating effect further reduces tissue resistance (*Part 2, 2004 Study Update*)
5. Broadhead edge bevel**.** Single bevel edges offers an advantage *when bone is encountered*. Depending on broadhead profile and mechanical advantage, single bevel broadheads show a penetration gain varying from 30 to almost 60 percent. When no bone is encountered, single bevel penetration gain is of less significance (*Part 1, 2005 Update; Why Single-Bevel Broadheads*). Increased bone penetration of single bevel broadheads occurs because of their tendency to split bone apart rather than force a path through. The frequency and magnitude of “single bevel induced” bone splits is greater in rib, humerus, or femur than in scapula, pelvis, sternum, or spine, but occurs frequently with all.
6. Broadhead tip design**.** Testing showed the Tanto tip outperformed all other tip designs when encountering bone, likely because it best resists damage and skipping as the arrow passes through the curved surface of animal bone (*Part 1, 2005 Update*).

Elk are big, tough animals and it’s to your advantage to approach an upcoming archery hunt with as many of the preceding factors as possible in your favor. Most of these aspects of arrow design are easy to address as part of your normal hunt preparation, and careful preparation will pay off when the opportunity for a shot presents itself. Our own current arrow setups may serve as examples to get you started:

AF. 29” tapered carbon shaft (65-80 spine) with 4 fletch, 3” feathers (350 grains). Brass insert (60 grains). 175 grain, two blade, single-bevel broadhead with a 75 grain steel adaptor (MA=2.33). Total arrow mass = 660 grains. FOC = 22%. Designed for 55 lb. @ 28” recurve.

BB. 29” tapered carbon shaft (345 grains) with 3 fletch, 4” vanes. Brass insert (100 grains). 315 grain, single-bevel, grizzly-type broadhead (MA=2.4). Arrow mass = 760 grains. FOC=25%. Designed for a 60 lb. @ 27” compound.

If you have decided to change some aspects of your current arrow setup as a consequence of reading this article, you will need to experiment a bit with different arrow components to get things just right. A little experimentation will be fun as well as rewarding. Try it and see.

Among the 11 arrow penetration factors, compound shooters may find arrow mass problematic. Compound bow manufacturers have hyped arrow speed as the single most important criterion and consequently, light, fast arrows seem to have become the norm. An increase in arrow mass requires a decrease in velocity, however, creating a tradeoff between using 1) a heavier, more lethal arrow that requires better distance estimation skill, versus 2) a lighter, less lethal arrow that has a flatter trajectory and smaller error associated with misjudging distance.

This is how we recommend that you resolve this tradeoff. First and foremost*, hitting an elk with an arrow is not the goal, rather finding every elk you hit is what really matters*. Shot placement remains important, but need not suffer with heavier arrows. It’s a simple matter to adjust your sight pins for a different arrow trajectory. Laser rangefinders can improve your distance estimation in both the learning phase and at the time of a shot. You may find only a small additional error in misjudging distance, especially under 30 yards where most elk are shot. For example, given a 60 lb. compound, increasing your arrow weight from 500 to 700 grains only increases the error by about 1.5 inches, when misjudging distance by 5 yds. at an actual distance of 25 yds. In all cases, limit your shots to distances where a likely error in distance estimation will not be critical. Finally, you may find that heavier, weight forward of center arrows shoot quieter and fly better than lighter arrows, benefitting both accuracy and precision. In the end, only you can decide how to resolve this tradeoff. We hope the arrow lethality information presented here will help with that decision.