2004 Broadhead & Arrow Lethality Study Update, Part 2
by
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Part 1 of this update report covered the current status of the new Broadhead & Arrow Lethality Study, and presented information relative to the first round of testing on Asian Buffalo: about the animal itself; sharpening broadheads for use on buffalo; data from ancillary test on fresh buffalo skin; and *initial* data relative to broadheads.

In this part, we will look at *initial* data relative to arrow shafting, shot placement, shooting angles and some ancillary test data relevant to the skip angles of broadheads on buffalo ribs, as well as some comments and observations regarding arrow impact force and penetration. **At the conclusion is a TIP. I URGE all who anticipate hunting the Asian Buffalo to read and heed. There were some potentially dangerous buffalo confrontations encountered during this testing.**

Shafts. 'Drag factors' are important. *The following shaft information comes from analysis of comparable shots, using the same broadhead.*

As with the broadhead testing, all data presented here is from set-up shots on freshly killed buffalo. All shots were from 20 yards, measured with a laser range finder.

The best 'penetrator' was a double shaft; a 2018 Easton with a Carbon Express Youth Arrow inside. Total mass, with modified Grizzly broadhead, was 960 grains. This shaft combination is not a 'slip-fit'. A ¼" long wrapping of fine silk thread was served on each end of the carbon shaft to achieve a tight slip-fit. It is the best shooting double shaft I have used.

Next best in penetration was a 2219 Easton with a 1916 Easton shaft inside. 'Forward weighting', with 135 gr. of steel rod back of the insert, was required to 'weaken' the dynamic spine and achieve good arrow flight from the bow used in the shaft testing. Total mass of this arrow was 1090 gr., with the modified Grizzly broadhead. Its average penetration *on comparable shots* was 11.7% less than the 2018/carbon express double shaft arrow.

Though the 2219/1916 shafted arrow had an *impact momentum* of 0.581, and the 2018/Carbon Express an *impact momentum* of 0.546, the 2018 shaft is 19.04% smaller than the broadhead’s ferrule diameter, while the 2219 is but 10.88% smaller. The penetration difference correlates with previous findings relative to ‘shaft drag’ and the ‘shaft diameter to ferrule diameter ratio’.

The big surprise was Troy Breeding’s TAPERED hickory shafts. They out penetrated my much-loved Forgewoods (by a ‘whopping’ 0.58” average penetration – or “pretty much the same” – but that’s not bad good company to be in!).

On buffalo, these tapered hickory shafts out penetrated barrel tapered (BT) hickory shafts *by a substantial margin*, though the BT shafts averaged 50 grains more mass. This, *I think*, is because the skin closes down around the shaft, and has to be spread apart again as the BT shaft’s diameter increases in the central ‘barrel’ portion, but there *may* be some other factors at work too, such as the percentage of weight forward-of-center (FOC).

A new (to me) finish was used on these hickory shafts. It’s the ‘slickest’ and toughest wood shaft finish I’ve come across. With blood on my hand it was difficult to hold on to the shafts. That may be a factor. Their finish is decidedly ‘slicker’ than that on the Forgewoods. ‘Relative slickness’ of shafts needs to be examined in more detail.

The next best penetrators were the 0.334” dia. Forgewoods. Following very closely was the Grizzly Stik Safari. I did not have a sample of the heavier “Big Five” Grizzly Stik to test with, but now do. Hopefully, they will get tested this coming year.

I DO like the way the Grizzly Stik shoot. Achieving excellent arrow flight with them was extremely easy. They, too, are a tapered shaft. I *think* they will offer some advantage in penetration, much as with the tapered hickory shafts.

With the tapered shafts there is a slightly higher mass FOC. This *MAY* be a penetration factor. There *should* also be less arrow flex on impact with a tapered shaft, due to the lower amount of mass towards the rear of the arrow. Less flex would mean less loss of resident impact force to vibration and shaft drag. Both *might* be offering some contribution to the penetration characteristics of the shafts. Future testing should illuminate these *suppositions*.

When utilizing the above 'standard test broadhead', the above shafts fell into just two groups, with only fractional differences in *average* performance within each group. There are the double shafts and the other shafts.

Throughout this buffalo test, the 'woods' and GrizzlyStiks *always* reached at least into the second lung (again, with the 'right' broadhead and 'kill zone' hits, at good shot angles). The double shaft arrows *consistently achieved* deeper penetration. The 2018/Carbon Express *consistently* reached the off-side thorax wall. The 2219/1916 *often* did so. Many of the double shaft arrows stuck solidly into the off-side rib, with some penetrating it. (This *occasionally* was achieved with the wood-Grizzly Stik group.)

Tipped with the modified Grizzly broadhead, any of these shafts proved adequate to **consistently** deliver a double lung hit when *impact momentum* was 0.52, or higher, **AND the shot was correctly placed**. (See "Shot Placement", below.)

Here are the 'impact force levels' of these two 'groupings' of arrows. The 'woods' and GrizzlyStiks *averaged* 36.77 Ft. Lbs. of *impact kinetic energy* and 0.5239 Slug-Ft./Sec. *impact momentum*. The 'double shafts' averaged 36.62 Ft. Lbs. of *impact kinetic energy* and 0.5790 Slug-Ft/Sec. of *impact momentum*.

Using these same shafts with other broadheads of lower mechanical advantage, the data UNIFORMLY indicates that impact momentum must be higher to achieve adequate penetration to <u>assure</u> a double lung hit. From the limited data, it <u>*appears*</u> that impact momentum of 0.65 would be sufficient with *most* of the better 2 blade broadheads, <u>when</u> *shafting of a mass approximating the ones above is used,* <u>and</u> a favorable shaft diameter to ferrule diameter ratio is maintained. (Ferrule Dia. larger than shaft Dia.) The approximate *average* mass is 830 gr. for the 'woods' and GrizzlyStiks' and 980 gr. for the double shaft arrows.

Please remember that these early test were done at what appears to be <u>minimum threshold impact force</u> – *the level that would send the* **very best** *penetrating arrow/broadhead combination CONSISTENTLY up against the off side chest wall on a well placed shot.* More *impact force* would increase the performance of any of these combinations, providing an amplified 'margin of error' (In cases of 'forward' shoulder hits. See "Shot Placement", below).

Throughout the 'shaft testing' phase I used the SLOWEST of my 82# longbows. By trial and error, it was found to deliver, at the testing distance, the *impact force* I was seeking. Higher velocity and higher impact force testing is a planned focus for a future buffalo trip. One would *expect* to see a somewhat lower arrow mass for the 'adequate' level, and increased performance from the higher mass arrows.

There are certainly a number of other shafts that should work equally well, and several dozen of additional types are on hand for future testing. Testing with *extreme* FOC weighted carbon shafts is also planned.

Comments and observations from the skin test (See Part 1) and shaft test. That a correlation disparity between arrow *impact kinetic energy* and measured penetration *in real tissues* certainly *appears* to exist has been noted and reported from my earlier studies. Data from both the skin test and the arrow shaft testing presented here is *suggestive* of the same.

ALL arrow penetration data from my earlier studies is strongly suggestive that *impact momentum* is a far more valid factor *for use in developing* 'indicators' of penetration than is *impact kinetic energy*, at least in *real animal tissues*.

All my data from shots into *real animal tissues,* to date, is also *highly suggestive* that the greater the contribution of resident arrow mass to *impact momentum*, the greater the penetration *in real tissues* will be, *when all else is equal.* In other words, all the information I have from shots *on real tissues* indicates that when two arrows. identical in all aspects except their physical weight, hit identical tissues with equal amounts of force, the one deriving the greater amount of that force from the weight of the arrow will penetrate deeper.

In the 'shaft test', there was a substantial difference in *average* penetration between the two groups of arrows, in favor of the heavier double shaft arrows. There was a virtually equal *average impact kinetic energy* between the two groups (36.77 Ft. Lbs. for the 'woods'/Grizzly Sticks and 36.62 Ft. Lbs. for the double shafts).

The double shaft arrows show an advantage in *average impact momentum* (0.539 Slug. Ft./Sec. for the 'woods' and GrizzlyStiks and 0.5790 Slug Ft./Sec. for the double shafts). Both groups were tested with identical broadheads, of equal mechanical advantage.

The ‘woods’ and GrizzlyStiks showed an *average* total arrow mass that was 84.7% that of the double shafted arrows. As *impact kinetic energy* was virtually equal, the ‘wood’/Grizzly Stik group had to be traveling faster than the double shaft group at impact.

Using *kinetic energy* alone as a ‘predictor’ for the penetration, the penetration of both groups of arrows should be near equal. The double shaft arrows carry an *average* of 7.4% more *impact momentum*. Using momentum as a ‘predictor’, the double shaft group should penetrate deeper. Of course this example ignores other factors, such as the shaft drag, shaft diameter to ferrule diameter ratio, quality of arrow flight, ratio of resistance to penetration as velocity increases, etcetera.

When narrowing the parameters of comparison, to accommodate some of other factors, we come up with the closest match as being between the 2219/1916 double shafts and the Forgewood shafts. The diameter of the 2219 has a micrometer measured diameter of 0.344”, and the Forgewood 0.334. The ‘shaft diameter’, or ’shaft drag’, advantage goes to the Forgewood. The broadheads are identical, thus shaft to ferrule diameter ration advantage goes to the smaller shaft diameter Forgewoods. Both arrows show excellent flight, equal advantage.

The Forgewood *impacts* with 1.6% more kinetic energy, a virtual tie. The 2219/1916 impacts with 13.6% more *momentum*; advantage to the double shaft.

Of the above factors, momentum is the only advantage to the double shafted arrow. Kinetic energy would suggest that the two arrows should have near equal penetration. Momentum, if taken as an independent linear function, would indicate that the double shaft arrow should have 13.6% greater penetration.

The double shaft also has a higher percentage of its *impact momentum* derived from arrow mass. The double shaft arrow has 35.9% greater mass than the Forgewood and an impact velocity 14.9% less than that of the Forgewood. The 2219/1916 shafted arrow *showed an average gain in penetration of 33.29%* over the Forgewood. That is a substantial gain in *AVERAGE* penetration.

One often sees *kinetic energy* quoted as, and equated directly to, the ability of an arrow to penetrate tissues. Frequently it is referenced with total disregard of the arrow weight, type and design of broadhead (mechanical advantage), type and diameter of shaft (shaft Dia. to ferule Dia. ratio and 'drag' characteristics of the shaft and its finish), or any other potential factors relevant to penetration. Frequently, not even the quality of the arrow's flight is mentioned. For example, how often have you heard or read, "How much kinetic energy do I need to take a deer, or bear, elk, moose, kudu, Oryx … or an Asian Buffalo?" (Or the reverse, "X" amount of kinetic energy is adequate for …".)

From the above *actual data, from real shots, on real animals,* as well as *all* data, on *all sizes* of *real animals*, from *all* my previous testing, it is impossible for me to find any *meaningful* **"predictive"** *correlation* between *kinetic energy* and penetration to be able to answer.

In the above data, all the arrows had identical broadheads and virtually identical *impact kinetic energy*, with an extreme range variation from greatest to least *kinetic energy* of only plus or minus one-point-two (1.2) Foot-Pounds. According to some, penetration would be equal, and all the arrows equally effective for use on Asian buffalo. Such is not the case.

Nor was it the case with data drawn from the nineteen high velocity-light arrow mass shots taken on fresh buffalo carcasses. There the *impact kinetic energy* averaged 82.98 Ft. Lbs. That is one-hundred-thirty-eight percent (138%) MORE *impact kinetic energy* than the 2219/1916 double shaft arrow had. Of those 19 hits, all were well placed, "in the kill zone", and all were from the "ideal" shooting angle (See "Shot Placement", below). Only ten of the 19 penetrated enough to be lethal, and NONE of those shots were on an adult buffalo bull. With the heavy, and "kinetically 'impact energy' challenged", 2219/1916 arrow here describe, 100% of the 'kill zone' hits penetrated enough to be certain killing shots.

It also is of note that, on those few fast and light arrow shots, the *average impact momentum* was 0.5537 Slug Ft./Second. That's 10.3% more *impact momentum* than the Forgewoods, and only 4.7% less than the 2219/1916 double shaft arrow. Using momentum alone, one would predict the light arrows would penetrate somewhere between the Forgewood and the double shaft arrow. In actuality, they averaged 12.8% LESS penetration than the Forgewoods, despite their having 162.7% advantage in *impact kinetic energy* AND a 10.3% advantage in *impact momentum* over the *Forgewoods*. The penetration difference comes from the variance in *resistance* and the resultant *impulse* of the impact force.

Clearly, impact kinetic energy has insufficient direct correlation to be useful in developing 'penetration predictors' for real tissues. *Impact momentum* alone, though 'more predictive' than *impact kinetic energy*, is also not adequate as a 'solo predictor' of penetration. Impact momentum does, however, appear to be the 'starting point'. It does have a degree of *plausible correlation* to penetration. Based on all data currently available to me, it does not appear that the same can be said for *kinetic energy*.

It certainly *APPEARS* that the answer to accurately predicting the penetration capabilities and lethality potential of a 'razor sharp', broadhead tipped, arrow, on *real tissues, lies somewhere in the contribution that arrow mass makes to the amount of impact momentum, AND the 'drag' and 'resistance' factors of the arrow components in tissues AND THE COUPLING of these factors with the amount of impact momentum.* Providing, of course, that (1) *the arrow has good flight characteristics* AND (2) *the broadhead and arrow integrity remain intact throughout the course of penetration*.

Shot Placement for Asian Buffalo. A great deal of dissection and measuring of buffalo of differing sexes, ages and sizes was conducted. Here's just the 'nuts and bolts'.

From broadside, the 'kill zone' is narrow horizontally. Shot placement should be ON THE SHOULDER CREASE and 38% to 40% up the body (brisket to back). The easy way to be 'in the ballpark' is to divide the body height into quarters. Don't shoot at the bottom 1/4th. Shoot at the MIDDLE of the second 1/4th.

With that shot placement, the vertical 'kill zone' on an adult bull will be upwards about 5 ½" and downwards about 7". The bigger problem is horizontally. Six inches back of the shoulder crease and one is at the diaphragm. Any further back … gut hit.

The diaphragm moves significantly *forward* as one goes downward. A 'low and back' hit is REAL trouble. A hit back and above the 38%-40% vertical threshold is preferable to one back and below.

If arrow impact moves forward of the shoulder crease, any and all additional penetration one can get from their arrow becomes a marked advantage. Two-and-a-half inches to 3 inches forward of the crease, into the shoulder, and one has up to 10" of skin and meat to penetrate *before reaching the on-side* ribs of an adult bull!

<u>The IDEAL SHOT</u> is quartering away at 15 to 20 degrees. The AIMING POINT now moves 2 1/2’” to 3” back of the shoulder crease and in the same vertical position. This opens a larger shooting area (kill zone), with more room for error.

<u>*Shooting Angles*</u>: In evaluating shot angles, some ‘skip-angle’ testing was performed. Because of the overlapping ribs, broadheads are more likely to skip off buffalo than would be the case with an ‘open-rib’ animal. (Though some ‘skip shots’ on open ribbed animals have been recorded, when the broadhead’s orientation and point of impact with the rib were simply ‘wrong’. The 3 blade broadheads have the highest frequency of ‘skip’ in all the data to date.)

For skip-angle testing a series of shots was taken with broadheads of differing configurations. WHERE POSSIBLE, SEVERAL DIFFERENT BROADHEADS IN EACH ‘CATEGORY’ WERE USED. The categories tested were: (a) steep angled 3 blade; (b) long narrow 3 blade; (c) COI four blade that have all blades tapering to near the tip; (d) COI 4 blade that have a short ‘bleeder blade’ configuration; (e) 4 blade modular heads with “bone-breaker” tips; (f) wide 2 blade heads; and (g) long-and-narrow 2 blade heads.

All shots were from 20 yards. Six shots were taken at each shot angle with each ‘category’, up until their ‘skip angle’ was found.

Up to 25 degrees quartering from the rear there were no skips. At 30 degrees, the steep-angle three blade heads had near a 50% skip rate.

At 35 degrees the long and narrow three blade, bone breaker, modular heads and COI 4 blade heads that taper to the tip all had near 50% skip rates. At 40 degrees the 4 blade heads with short ‘bleeder blades’ and the wide 2 blade heads had from 33 to well over 50% skip rates.

The 2 best performers had no skips until the shooting angle reached 45 degrees. There these heads showed a skip rate of 42%.

The two broadheads with the best ‘skip angle’ were the Howard Hill and the modified Grizzly. There is an obvious advantage to long-marrow heads when shooting at extremely oblique impact angles. (It should be noted that the Howard Hill broadhead’s ferrule does have problems 'hanging up' on heavy bone, and with bending of the ferrule at the rivet.)

Note too that the advantage of long, narrow broadhead was manifest with the three
blade heads. The long-and-narrow 3 blade heads show a better skip angle than the 'short and wide' 3 blade broadheads.

IMPORTANT TIP: The Asian Buffalo shows that it is getting 'agitated' by making a VERY SLIGHT rocking of the head, raising first one horn tip, then the other. This MOVEMENT is SLOW and VERY SUBTLE. One will not even notice it unless aware to be looking for it. Some very aggressive animals were encountered during the testing, so watch out for this 'warning signal' when you hunt! It is often the ONLY prelude to a charge!

Though the forgoing represents only initial statistics, I hope all find the information here both of interest and useful. The new study has the potential of yielding enormous information, and the above exemplifies merely "the tip of the iceberg". I look forward to being able to pass along more results from the study in the future. Thanks to one and all for the support that has been received for the study during this past year, and a very special 'Thank You" to the individual who allowed access for the buffalo testing (and who must remain anonymous, as I failed to get his permission to divulge his name before compiling this update).

Buffalo country!

Campsite in Buffalo Country. Not visible are the heat, humidity and insects!

Just in case anyone thinks the testing is all fun and games!

Golf isn’t the only sport that has water hazards!

Trophy Bull. This shot shows near perfect placement when taken quartering from the rear, at 25 degrees.