The Use of Likelihood Ratios in Reporting Difficult Forensic Cases

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INTRODUCTION

The advantages of using a likelihood ratio for forensic evidence interpretation has long been recognised by Ian Evett[1]. This approach has gained increasing support especially in the areas of DNA and glass evidence interpretation.

When using a likelihood ratio approach, the probability of the evidence is evaluated under two alternative hypotheses.

The ratio of the probabilities of the DNA evidence under each of these two hypotheses is a measure of the weight of the scientific evidence and is known as the likelihood ratio (LR).

$$LR = \frac{P(E|C)}{P(E|\bar{C})} = \frac{\text{probability of the DNA evidence given the semen originated from suspect}}{\text{probability of the DNA evidence given the semen originated from a random male}}$$

In this simple case the LR numerator $P(E|C)=1$.

The LR denominator, $P(E|C)$, will depend on the particular alternative hypothesis. In the absence of any particular defence, we use random man i.e. the suspect is innocent and the match occurred by chance. Thus, the frequency of the profile bands in a relevant database is used to estimate the frequency of the profile in the population.

Unfortunately, not all forensic DNA cases are as simple as this and often there are situations where the LR numerator $\neq 1$. It is these cases where reporting a "frequentist" number becomes difficult. The following three cases illustrate this point.

1 Missing Person

Police believed a missing woman had been murdered but could find no body. A T-shirt was found which was identified as being similar to hers. The T-shirt had a bullet hole in the back and was heavily blood-stained. The missing woman had a father and brother still alive. Her mother was deceased. Reference blood samples from her brother(B) and father(F) were provided to compare with the blood stain from the T-shirt.

The DNA profile obtained from the blood stain on the T-shirt had two bands. One of these bands matched a band in the victim's father's profile(c). The other band matched what was determined to be the maternal band of the brother's profile(a). Therefore, the blood stain is either from a child of F and sibling of B or alternatively the blood is from some unrelated person and the observed match has occurred by chance. The LR allows us to weight these two alternatives.

$$LR = \frac{\text{probability of the DNA evidence if the blood stain is from a child of F and a sibling of B}}{\text{probability of the DNA evidence if the blood stain is from a random person.}}$$

It can be shown that $LR = \frac{\frac{1}{2}a + \frac{1}{4}(1-a)}{2ac}$ where a&c = frequency of the bands.

This equation is derived from a form of Bayes Theorem for multiple hypotheses and takes the prior probability into account:

$$P(M|B) = \frac{P(B|M)P(M)}{\sum P(B|M)P(M)}$$

Overall, it was 114 times more likely that the blood was from a child of F and sibling of B rather than from some unrelated individual.

2 Family Relationships

The accused in a rape trial was the victim's natural father, though she could not identify him. She had been raped on a hay bale in a barn. A DNA match was found between the accused's blood and the semen stain on the hay bale. At each of five loci a band in the semen stain profile matched that of the victim as well as the accused.

The reference blood sample from the accused had previously been ruled inadmissible by the court due to a consent issue. Therefore it was necessary to interpret the results without reference to that sample. The relatedness identified in the matches was used. A blood sample was obtained from the victim's mother. This showed that each of the crime bands which matched that from the victim was the paternal band.

The hypotheses for this case

$$LR = \frac{\text{probability of the DNA evidence if the semen originated from the victim's natural father}}{\text{probability of the DNA evidence if the semen originated from another random male}}$$

The numerator is the probability that the father will pass on the paternal band (q). There is a 50% chance (probability = 0.5) he will pass on q. (Unless it is a homozygote in which case probability =1; however assuming the true father is heterozygote is conservative,i.e.favours defendant.)

The denominator is the frequency of q in the database,i.e.an estimate of the frequency with which the paternal band occurs in the population.

Over five probes the likelihood ratio was 10,000 i.e. the DNA evidence is at least 10,000 times more likely if the semen on the hay originated from the victim's natural father rather than if it originated from a man chosen at random from the New Zealand population.

3 Mixture of DNA Profiles

A woman was found raped and murdered. Blood samples were obtained from three suspects and their DNA profiles compared to the DNA profile from the victim's swabs which showed a mixture present.

The four bands in the crime samples could all be accounted for between two of the suspects tested. Therefore the possibilities are:

C1 the semen on the swabs is a mixture of semen from suspect 1 and suspect 2
C2 the semen on the swabs is a mixture of semen from suspect 1 and some other random male
C3 the semen on the swabs is a mixture of semen from suspect 2 and some other random male
C4 the semen on the swabs is a mixture of semen from two random males unrelated to the suspects

To take all four of these possibilities into account in a single LR would require estimation of prior probabilities. This can be avoided however with the following conservative approach:

For example consider suspect 1

The strongest evidence would be $LR = \frac{P(E|C1)}{P(E|C3)}$

This would be 1/2ab.

The most conservative evidence would be $\frac{P(E|C2)}{P(E|C4)}$

The numerator $P(E|C2) = 1 \times 2cd$ with cd being the frequency of suspect 2's bands in the population.

For bands with frequencies abcd, the denominator $P(E|C4) = 24abcd$. This the calculation for mixture of two random males according to Evett[2]:

This gives $LR = {}^{2cd}/24abcd$

For this case for 5 loci it was reported as the DNA evidence was as least 113,000 times more likely if the semen from the swabs is a mixture of semen from suspect 1 and some other male rather than if it is from two other men selected at random from the racially-mixed New Zealand population.

REFERENCES:

[1] Evett, I.W., Buffery, C., Willot, G. and Stoney, D. (1991) J. For. Sci. Soc., 31(1):31-40.

[2] Evett, I.W.(1990) Forensic Science Progress 4. Springer, Berlin , pp141-179,