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SHORT COMMUNICATION

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Likelihood ratios for mixed stains when the number of donors cannot be agreed

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Abstract Suppose that part of the prosecution's evidence in some crime case is analysis of a blood stain, and that the traits E discovered in the stain suggest multiple donors. Then the prosecution will probably allege some specific inculpatory hypothesis H_0 about the sources of the stain, and $P\{E \mid H_0\}$ can be calculated. It is desirable to use this as the numerator of a likelihood ratio. However, in general the obvious denominator $P\{E \mid \sim H_0\}$ cannot be calculated, so unless the defense is sufficiently obliging as to stipulate to a specific choice among the potentially infinite number of more or less exculpatory alternative hypotheses, the desired likelihood ratio can't be evaluated. We show that nonetheless, in most cases there is an adequate inequality.

Key words Likelihood ratio · Mixed stain · DNA

Discussion

E — denotes some evidence consisting for example of a handful of RFLP bands using some probe.

H_0 — is the prosecution's explanation, such as that E comes from the suspect and the two victims.

H_i, $i \geq 1$ — are the alternative explanations, for example that E is explained by i random people.

Put $e_i = P\{E \mid H_i\}$ and $e' = P\{E \mid \sim H_0\}$.

We have heard the claim that the probability e' and therefore the likelihood ratio e_0/e' cannot be computed, and therefore that several possibilities e_0/e_i $i \geq 1$, must be computed and presented in court[1]. The first part is true enough since

$$\begin{aligned} e' &= P\{E \mid \sim H_0\} = P\{E \mid \cup_{i>0} H_i\} \\ &= \sum_{i>0} P\{E \mid H_i\} \cdot P\{H_i \mid \sim H_0\} \\ &= \sum_{i>0} e_i \cdot P\{H_i \mid \sim H_0\}. \end{aligned}$$

That is, e' depends on the allocations $P\{H_i \mid \sim H_0\}$ of prior probabilities, which typically depends on the sorts of arguments that the defense will make and therefore cannot be known or stipulated by the forensic scientist or the prosecution's expert witness.

However, it does not follow that a variety of calculations must be presented. Although the reasoning is simple we feel it is worthwhile setting out in advance rather than relying on the ability of the expert to think clearly under the pressure of cross-examination.

Even though there is no way to compute e' itself we can usually provide a very useful upper bound for it, and hence a lower bound for e_0/e'. If there is a largest among the e_i, $i > 0$, then denote it by e_{max} and then we have (continuing the computation above):

$$\begin{aligned} e' &= \sum_{i>0} e_i \cdot P\{H_i \mid \sim H_0\} \\ &\leq e_{max} \sum_{i>0} P\{H_i \mid \sim H_0\} \\ &= e_{max}. \end{aligned}$$

Therefore even though the desired likelihood ratio e_0/e' cannot be calculated explicitly, the prosecution can simply say that it is at least e_0/e_{max}, which can be calculated.

Limitation

When the blood stain evidence consists of multiple bands in an RFLP typing, e_{max} will surely exist (and will usually correspond to the minimum number of people sufficient to contribute the observed number of bands). However, if every allele of some discrete-allele system is represented – which can easily happen with DQα for example – then $P\{E \mid i \text{ contributors}\} \to 1$ as i increases and our method is

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[1] For example this procedure was mandated in the murder trial of O.J. Simpson

not helpful. In such a case if any incrimination is to be inferred from the evidence the onus is on the prosecutor to present effective arguments limiting the plausible number of contributors.

To illustrate, suppose the sperm fraction in a multiple rape case shows the THO1 alleles 6, 9, 9.3, and 10, with respective frequencies $a = 22\%$, $b = 17\%$, $c = 33\%$, and $d = 2\%$. The prosecution believes that the 9, 9.3 suspect and one other man contributed. The defense's best claim is that there were *three* assailants not including the suspect. Under this interpretation the evidence is actually exculpatory, with a likelihood ratio of

$$\frac{1}{15bc\{3(a+b+c+d)^2 + a^2 + b^2 + c^2 + d^2\}} = 0.65.$$

But if the prosecution can persuade the jury that the number of assailants is only two, then the likelihood ratio grows to

$$\frac{1}{12bc} = 1.5.$$

Other situations

Similar reasoning can also be used to sidestep some other kinds of ambiguity. For example:

Unknown accomplice.

If the prosecution believes that the stain comes from the suspect and an accomplice of unknown race, then there is no prejudice in calculating $P\{E \mid H_0\}$ as if the accomplice has the race that least commonly provides the unexplained traits.

Unknown race.

When the prosecution alleges that the stain comes from the suspect alone and the alternatives are that it came from an unknown person, there is no need to present multiple calculations corresponding to various races. There is no prejudice to the defense in assuming the most probable race for the perpetrator when calculating the denominator of the likelihood ratio.

Conclusions

In summarizing blood stain evidence to the court it is a common practice to present multiple calculations to the court, corresponding to varying assumptions. This practice may (or may not) impress the court with the expert's technical wizardry, but it usually has no logical merit. If the likelihood ratios comparing the various prosecution versus defense hypotheses are all large, an adequate and common sense approach is to present only the smallest ratio. The prosecutor can then honestly and effectively argue that the evidence is *at least* so strong, without needing to argue as to the *a priori* likely number or race of contributors, and without giving extra data of uncertain and unexplained relevance.