

The Precautionary Principle meets the Hill Criteria of Causation

A Case Study of Tuberculosis among Gold Miners in South Africa

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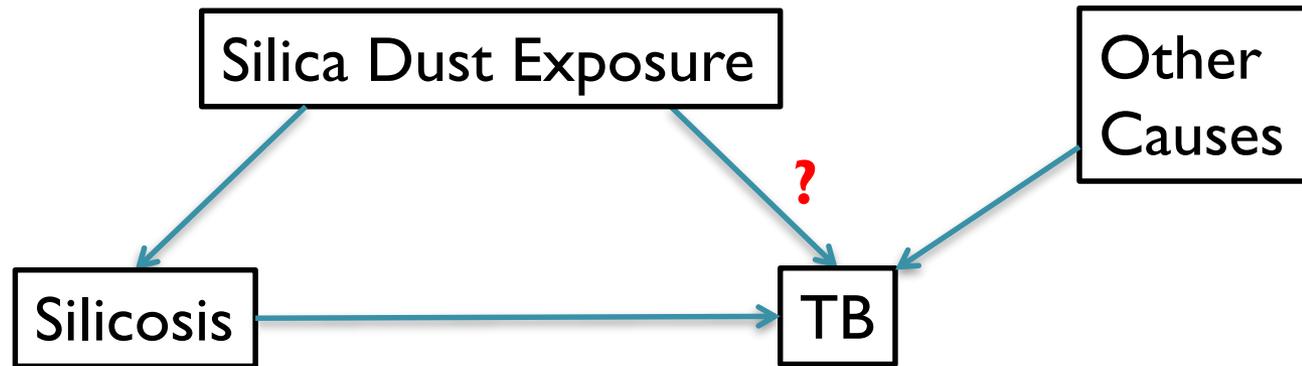
a place of mind

THE UNIVERSITY OF BRITISH COLUMBIA

Tuberculosis (TB) in South African (SA) Goldmines

- SA gold miners have the highest rate of TB among all working populations in the world (World Bank, 2014).
- Studies suggest that silica dust can impair the ability of the macrophage in the lung to inhibit the growth of TB bacillus (Ebina et al., 1960; Kettle, 1924; Snider, 1978).
- In May 2016, the SA High Court approved a class action lawsuit against approximately 32 mining firms for 500,000 miners who contracted silicosis or TB.

But it's complicated...



- Must mining companies compensate workers who who have TB, but not silicosis?
- Mining company representatives say **no** because:
 1. Among those who don't have silicosis, the association between TB and silica dust exposure is weak.
 2. TB has many other causes.

Precaution and the Hill Criteria

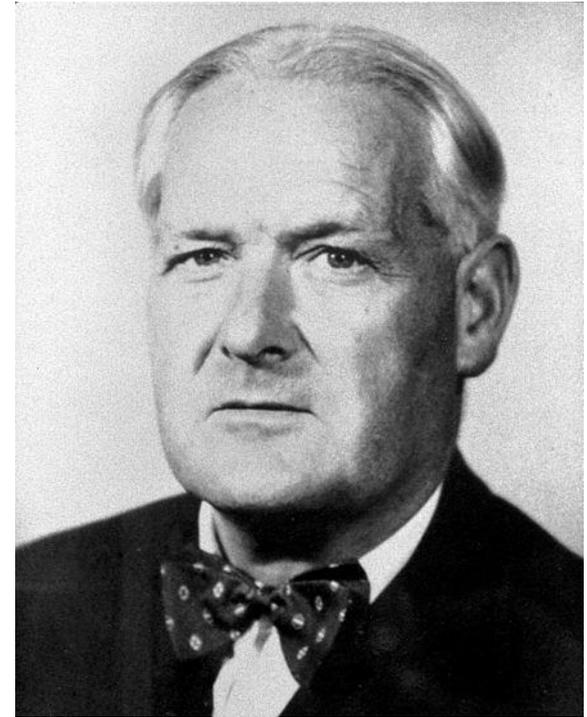
- We consider this case in connection with arguments that the **Hill criteria of causation** are **anti-precautionary** because...
- They tend to underestimate risks in the context of **multi-causal** relationships...
- And thereby unjustifiably obstruct or delay measures to protect public health.

Outline

- The Hill Criteria of Causation
- The Precautionary Principle and the Multi-Causal Objection
- A Response and Positive Proposal
- TB among SA Goldmine Workers, again

Sir Austin Bradford Hill (1897-1991)

- Known in epidemiology and public health for:
 1. Empirical work on adverse health effects of smoking.
 2. Pioneering randomized clinical trials.
 3. And what are known as the “Hill Criteria of Causation.”



The Hill Criteria

- From, “The Environment and Disease: Association or Causation?” (see handout).
- Read by Hill at the 1965 Presidential address to the Occupational Health section of the Royal Society of Medicine.

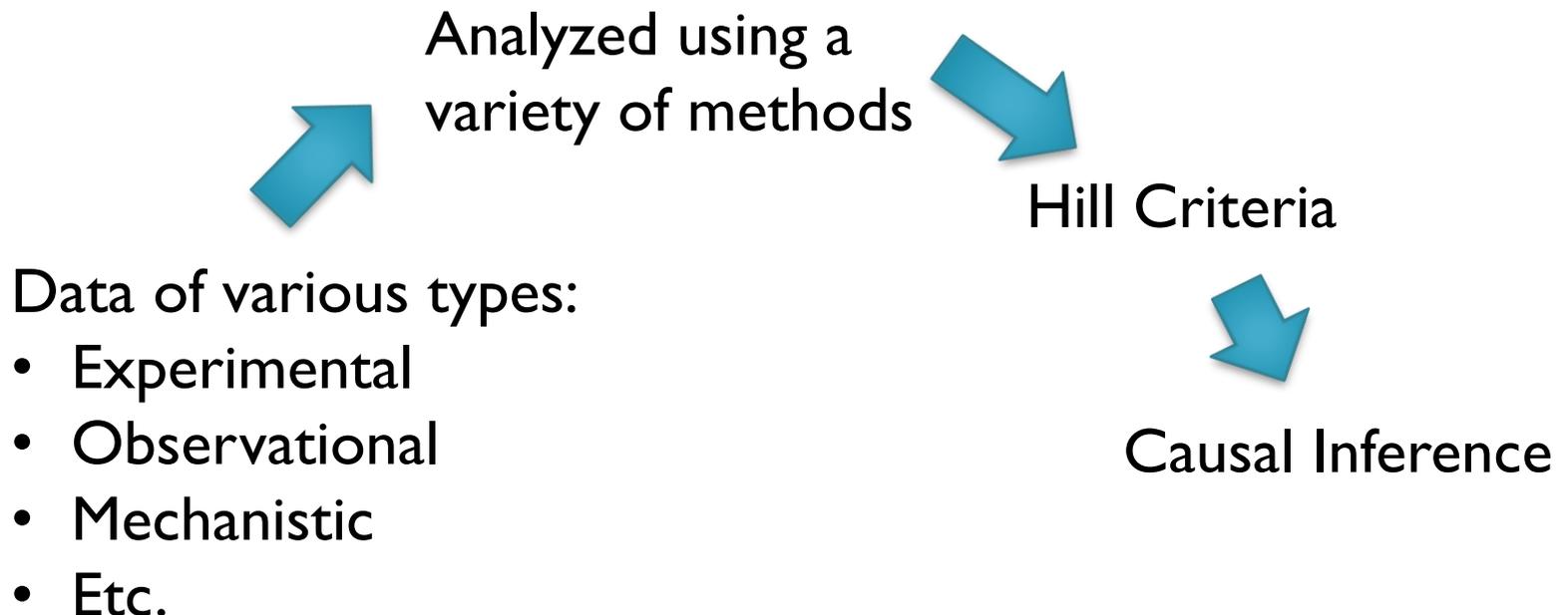


A Distillation

1. **Direct evidence** ... that a probabilistic association between intervention and outcome is causal and not spurious [strength, experiment, temporality];
2. **Mechanistic evidence** ... that connects the intervention and the outcome [biological plausibility, biological gradient];
3. **Parallel evidence** ... related studies that have similar results [coherence, consistency, and analogy]. (Howick et al. 2009, 186-187)

How to View the Hill Criteria

- The Hill criteria are best construed as guidelines for integrating results from a variety of different types of data and causal inference methods.



Caveat I: Not Necessary or Sufficient

- Hill insisted that none of the criteria (or “viewpoints” as he called them) were necessary or sufficient for establishing a causal relationship (1965, 299).
- “What they can do with greater or less strength, is to help us make up our minds on the fundamental question—is there any other way of explaining the set of facts before us, is there any other answer equally, or more, likely than cause-and-effect?” (Hill 1965, 299).

Caveat 2: Consequences of Error

- What evidence is sufficient should depend on the consequences of error.
- “On fair evidence we might take action on what appears to be an occupational hazard, e.g., we might change from a probably carcinogenic oil to a non-carcinogenic oil in a limited environment and without too much injustice if we are wrong. But we should need very strong evidence before we made people burn a fuel in their homes that they do not like or stop smoking the cigarettes or eating the fats and sugar that they do like” (Hill 1965, 300).

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The Precautionary Principle (PP)

- Motivated by the idea that measures to protect the environment and public health should be able to proceed even in the presence of substantial scientific uncertainty about cause and effect relationships.
- “All scientific work is incomplete... That does not confer upon us a freedom to ignore the knowledge we already have, or to postpone action that it appears to demand at a given time” (Hill 1965, 300).

Epistemic PP

- Insists that the goal to prevent harms to the environment and public health are relevant to decisions about what should count as sufficient evidence for establishing policy relevant scientific claims.
- Example: European Union's REACH legislation.

Argument from Inductive Risk

- Claims that values relating to the seriousness of false negatives and false positives should influence decisions about what is taken to be sufficient evidence.
- “before we can accept any hypothesis, the value decision must be made in light of the seriousness of the mistake, that the probability is *high* enough or that, the evidence is *strong* enough, to warrant its acceptance” (Rudner 1953, p. 3).

Multi-Causality

- “A given disease can be caused by more than one causal mechanism, and every causal mechanism involves the joint action of a multitude of component causes” (Rothman and Greenland 2005, S145).
- TB for Example: Infection with *Mycobacterium tuberculosis* is necessary but far from sufficient (90% of TB infections are latent), and many other contributing factors exist, such as compromised immune function and smoking.

The Multi-Causality Objection

- “Bradford Hill’s explicit approach to deriving causation from association was essentially based on monocausality, that is, on finding the specific cause of a specific disease” (Gee 2008, 259).
- For Example: Multi-causal relationships often do not generate strong statistical associations (criterion 1), may not be consistent across contexts (criterion 2), and do not involve a specific link between cause and effect (criterion 3).

A Tendency for False Negatives

- “The observed associations will, in most cases, be multiple, weak, confounded, interactive and often inconsistent. In such circumstances, the asymmetry that characterizes the Bradford Hill criteria is even more pronounced, that is, the *presence* of the criteria can be robust evidence *for* a causal association, while the *absence* of the criteria is not robust evidence *against* a causal association” (Gee 2008, 260-261).

Criteria of Precautionary Action

- As an alternative to the Hill criteria, David Gee proposes a list of “criteria of precautionary action” (Gee 2013, 653).
- Please see page 2 of the handout!



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It all Depends on the Weighting

- We suggest that no claims about the propensity of the Hill criteria for false negatives or false positives can be made without specifying how those criteria should be *weighted*.
- Typically not all criteria are satisfied and none are necessary or sufficient, so which ones are most important?
- Different answers to this question can result in very different propensities for false positives and false negatives!

Example: Strength & Coherence

- The implicit practice in US Surgeon General reports on smoking appears to have been to place greatest weight on strength and coherence (cf. Parascandola et al. 2006).
- But many other weightings are possible, and *many would result in very different propensities for false positives and false negatives.*

Why one Weighting rather than Another?

- Choice of weightings might depend on what types of evidence are available in a given field (e.g., mechanistic evidence might be more important when experiments are not possible).
- *And it might also depend on the balance of harms associated with false positives and false negatives.*



Not an Alternative

- We claim that Gee's "criteria of precautionary action" are not an alternative to the Hill criteria.
- Instead, they are a proposal about how to *weight* the Hill criteria when risk of harms associated with false negatives are high but those of false positives are low.

Reorganizing Gee's Criteria

1. **Epistemic:** Evidence for the causal relationship (criteria 1 and 8 from Gee's list).
2. **Uncertainty:** "a low 'knowledge/ignorance ratio'" (criterion 2).
3. **False Negative Harm Intensifiers:** Reasons that the harm, if it exists, may be especially severe or difficult to contain (criteria 3-7 and 9).
4. **False Positive Harm Mitigators:** Reasons to think the costs of regulation would be low even in the case of a false positive (criteria 10-12).

In other words...

- Both of the evidential considerations on Gee's list, fall into the category of ***parallel evidence***, wherein related studies with similar results are called upon to bolster a causal claim (Howick et al. 2009, 187).
- So, the “criteria of precautionary action” assert:
- *Parallel evidence is sufficient to justify precautionary action when scientific uncertainty, false negative harm intensifiers, and false positive harm mitigators are present.*

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Silica Dust and TB

- Support for the claim that silica dust exposure causes TB separately from silicosis relies mostly on mechanistic and parallel evidence (Dostert et al. 2008).
- Some studies do find that silica dust exposure and TB are associated even when silicosis is controlled for (teWaterNaude et al. 2006).
- But silica dust exposure is difficult to measure, making the strength of association uncertain.

Precautionary Actions

- Several precautionary actions are possible in the case of SA gold mines and TB:
 1. Reducing silica dust exposure within mines (e.g., through improved ventilation).
 2. Improved living conditions for miners.
 3. Improved health care and TB screening for miners.
 4. Changes to compensation practices, to make compensation easier and quicker for miners to obtain.

Weightings of Causal Criteria, encore

- Justifying compensation for miners with TB, but not silicosis, would be more difficult if strength of association were the most heavily weighted criterion.
- Indeed, arguments made against including TB in the class action suit by mining company advocates turned on heavily weighting strength of association.

Against the Class Action Suit

- Advocates representing mining companies, such as Gold Fields, argued against the certification of the class action suit for miners with TB.
- They claimed that the association between silica dust exposure and TB among those without silicosis is weak (Daily Maverick, 2016).
- “The elephant in the room on TB is that it is a social disease, but that does not mean that mines can be held liable for TB” (ibid).

On the other hand...

- It is much easier to justify compensation for miners with TB if parallel or mechanistic evidence is given more weight.
- Do Gee's "criteria of precautionary action" apply in this case?
- In other words, is this a case involving:
 1. *scientific uncertainty,*
 2. *false negative harm intensifiers, and*
 3. *false positive harm mitigators.*

False Negative Harm Intensifiers

- Nearly 90% of SA gold miners have evidence of latent infection (Hanifa et al., 2009).
- TB can become a chronic disease that leads to permanent lung function loss (Hnizdo et al., 2000).
- There are increasing concerns about multi-drug resistant TB (Marais et al., 2013).
- Miners often carry TB back to their communities of origin.

False Positive Harm Mitigators

- Silica dust exposure is known to cause silicosis, so reduction of silica dust exposure is a good thing no matter its relation to TB.
- Other measures to reduce TB, such as improved living conditions and health care for miners, are relatively low cost and obviously good in their own right.

Conclusions

- Applying the Hill criteria to concrete cases requires specifying a weighting.
- As the case TB among SA gold miners illustrates, judgments about the relative harms of false positives and false negatives can be relevant to such decisions.
- The above answers the multi-causality objection to the Hill criteria, and illustrates the precautionary principle in an epistemic role.

References

- Daily Maverick. (2016). GroundUp: Mines not liable for TB, silicosis hearing told. Available from <http://firstthing.dailymaverick.co.za/article?id=71980#.V9gwH4WcFm9>
- Dostert, C., Pétrilli, V., Bruggen, R. Van, Steele, C., Mossman, B. T., & Tschopp, J. (2008). Innate Immune Activation Through Nalp3 Inflammasome Sensing of Asbestos and Silica. *Science*, 320 (May), 674–677.
- Ebina, E., Takahani, I., & Hasuika, U. (1960). Effects of quartz powder on tubercle bacilli and phagocytes, *Am Rev Respir Dis*, 82, 516.
- Gee, D. (2008). Establishing evidence for early action: the prevention of reproductive and developmental harm. *Basic & clinical pharmacology & toxicology*, 102(2), 257-266.
- Gee, D. (2013). More or less precaution ? In *Late Lessons from Early Warnings: Science, Precaution, Innovation*, European Environment Agency, (Publications Office of the European Union, Luxembourg), 643–669.
- Hanifa, Y., Grant, A. D., Lewis, J., Corbett, E. L., Fielding, K., & Churchyard, G. (2009). Prevalence of latent tuberculosis infection among gold miners in South Africa. *International Journal of Tuberculosis and Lung Disease*, 13(1), 39–46.
- Hill, A. B. (1965). The Environment and Disease: Association or Causation? *Proceedings of the Royal Society of Medicine*, 58, 295–300.
- Hnizdo, E., & Murray, J. (1998). Risk of pulmonary tuberculosis relative to silicosis and exposure to silica dust in South African gold miners. *Occupational and Environmental Medicine*, 55(7), 496–502.
- Howick, J., Glasziou, P., & Aronson, J. K. (2009). The evolution of evidence hierarchies: what can Bradford Hill’s “guidelines for causation” contribute? *Journal of the Royal Society of Medicine* 102(5), 186–194.
- Kettle, E. H. (1924). The Demonstration by the Fixation Abscess of the Influence of Silica in Determining B. Tuberculosis Infections. *Silica and Experimental Tuberculosis*, m(1), 158–165.
- Marais, B., Mlambo, C., Rastogi, Nalin, Zozio, T., Duse, A., Victor, T., Marais, & E., Warren, R. 2013. Epidemic Spread of Multidrug-Resistant Tuberculosis in Johannesburg, South Africa. *Journal of Clinical Microbiology* 51(6): 1818–1825.
- Parascandola, M., Weed, D. L., & Dasgupta, A. (2006). Two Surgeon General’s reports on smoking and cancer : a historical investigation of the practice of causal inference. *BioMed Central*, 11, 1–11.
- Rothman, K. J., & Greenland, S. (2005). Causation and causal inference in epidemiology. *American Journal of Public Health*, 95(SUPPL. 1), 144–150.
- Rudner, R. (1953). The scientist qua scientist makes value judgments. *Philosophy of Science*, 20, 1-6.
- Snider, D. (1978). The Relationship between Tuberculosis and Silicosis. *American Review of Respiratory Disease*, 118(1), 455–460.
- teWaternaude, J. M., Ehrlich, R. I., Churchyard, G. J., Pemba, L., Dekker, K., Vermeis, M., White, N., Thompson, M., & Myers, J. E. (2006). Tuberculosis and silica exposure in South African gold miners. *Occupational and Environmental Medicine*, 63(3), 187–92.
- World Bank (2014). Southern Africa Tackles Tuberculosis in the Mining Industry. <http://www.worldbank.org/en/news/feature/2014/03/24/southern-africa-tackles-tuberculosis-in-the-mining-industry>