Objectifying Uncertainty: History of Risk Concepts in Medicine

Thomas Schlich

1. A technology for creating certainty

The issue of risk has become so common in contemporary medicine that social scientists speak of a veritable "risk epidemic" in the medical literature since the 1960s (Skolbekken, 1995). The use of the term "risk" implies a specific strategy of dealing with uncertainty based on calculations of probabilities (Short and Clarke, 1992a,b: 317–318). Probability-based logic helps medicine "to approach the uncertainties of diagnosis, therapy, and prognosis, and the clinical judgment that lies at their heart", as medical sociologist Renée Fox (2000: 410–411) points out. This strategy of objectification can be traced back to the Enlightenment period, and by the end of the 18th century, mathematical and quantitative methods were being applied quite frequently in order to create certainty in medicine (Magnello and Hardy 2002: iv).

Historically, however, the idea of risk has emerged in an economic context. It referred to the danger of losing money in business, especially on loans, in gambling and in insurance (Gigerenzer et al., 1989: 20–26). The earliest link to health issues can be seen in life insurance companies that needed to decide on the conditions under which they would accept applicants for a policy. Already the first life insurance company, the Equitable in England, charged extra premiums in 1762 for applicants with gout, hernia and no history of smallpox (Rothstein, 2003: 61–62). As a basis for their policy, the companies used mortality tables. The technique of drawing up mortality tables goes back to vital statistics, which used records of births and deaths in a locality or country to provide knowledge about the statistical regularity of health conditions within populations. This tradition started with the bills of mortality that were published in 1562 by the city of London to keep track of plague deaths as a warning of a major outbreak (Gigerenzer et al., 1989: 20–21). In the 16th century, the London merchant John Gaunt began to apply his commercial accounting practices to mortality lists. The resulting tables were published in 1662 under the title "Natural and Political Observations Made Upon the Bills of Mortality". They enabled a systematic comparison between past and present mortality numbers, parishes and city quarters, as well as death causes and gender specificities. This type of argumentation was found persuasive by British physicians and subsequently applied to medical questions (Rusnock, 2002: 40–50).

Within the emergent commercial and consumer culture of the period, counting and accounting came to be the preferred method of assessment in many different areas, among them medicine. The British hospital and dispensary movement, for example, induced doctors and lay sponsors to count recovery and death rates within these institutions and to calculate success rates of specific cures. Broadening their perspective beyond the traditional individualistic approach of medicine, doctors and administrators now focused on the well-being of the whole population or specific groups within it – such as the laboring poor, soldiers, women, children, rather than on individual patients. This applies to the evaluation of clinical experience too: An analysis of British medical journals from 1733 to 1829 shows the gradual reduction in dependence on single case reports and a growth in the publication of larger series, some of which were even analyzed by what can be called proto-statistical methods. In 1747, the British Navy physician James Lind (1736–1812) conducted his famous experiment on the treatment of scurvy amongst sailors, a procedure that can be interpreted as an early type of

controlled clinical trial. By administering different dietary supplements to five groups of two patients each over 2 weeks and then comparing the results among them and with untreated patients, he identified citrus fruit as an effective treatment for scurvy. Lind belonged to those British doctors who, in the second half of the 18th century, perceived the need for the empirical evaluation of remedies by comparative trials with results expressed by numbers. These physicians wanted to base clinical medicine on elementary numerical analysis of compilations and observations made on distinct groups of patients, not on experience with individual patients. For them arithmetic calculation was a way out of the maze of contradictory observations. As a result, by the first decades of the 19th century a more or less tacit acknowledgment of the utility – and even necessity – of numerical observations in clinical medicine emerged in the British medical literature (Tröhler, 2000: 16–21, 69–72, 115–124).

The British case is just one example of a more general trend which is most famously exemplified by Pierre Charles Louis (1787–1872). The French physician proposed to apply the numerical method and quantify the available facts on the benefits of particular treatment methods in order to achieve a statistical measurement and comparison (Matthews, 1995). Probability theory and statistics – the mathematics of uncertainty – were used for ridding medicine of "the arbitrary, the idiosyncratic, and the subjective" (Gigerenzer et al., 1989: 288). In the late 19th and early 20th centuries statistical methods were being used on a number of medical problems from evaluating tests for the efficacy of medical treatment to determining the heredity of tuberculosis. Statistics now appeared to be the handmaid of medicine, as Karl Pearson (1857–1936) characterized it (Magnello, 2002: 107–108). Generally speaking, the use of statistics in therapeutics was part of the process of objectification through which science entered medicine in a big way (Gigerenzer et al., 1989: 47). Starting in the 1830s, statistics also contributed enormously to public health. In his 1829 textbook "Elements of Medical Statistics" Francis Bisset Hawkins (1796–1894) predicted that the application of statistics to medicine would not only provide a basis for reliable diagnoses and effective treatments, but also allow for the evaluation of the impact of living conditions on life, health and labor (Magnello and Hardy, 2002: vi–viii).

In order to determine the influence of housing and sanitation on differences in mortality, investigators like William Farr (1807–1883) and Louis René Villermé (1782–1863) studied death rates by district, especially during cholera years (Gigerenzer et al., 1989: 261). Health data from vital statistics gained additional political significance in the course of the 19th century when they came to be understood as essential for assessing the state of health of a nation (Rothstein 2003: 30). Eventually, the technological approach to health embodied in vital statistics and mortality tables was applied to the risk of getting sick and elaborated in the form of the risk factor concept.

2. Predicting illness

The risk factor approach in a modern sense emerged in the 1950s and 1960s when the notion of probability came into use in the epidemiology of chronic disease (Aronowitz, 1998: 111; Jasen, 2002: 17). However, speculations on who would fall ill with particular diseases and for which reasons had been an element of medical literature for a long time. Though, as Patricia Jasen shows in her historical study, the word "risk" was only occasionally used in 18th and 19th century case histories of breast cancer patients. When doctors discussed the factors that might have played a role in the genesis of the disease they considered all of the characteristics of the patients that were supposedly associated with a cancerous tendency or "liability", as it was called at the time. Similarly to the modern use of the notion of risk, the term "predisposing" cause was frequently used to identify factors which were believed to have increased a patient's chance of getting the disease, even if they did not explain the onset of illness. In addition, doctors often aimed at determining which women were vulnerable. Such considerations could even lead to interventions like prophylactic mastectomy in order to prevent the outbreak of cancer.

Predisposing causes of breast cancer were traditionally understood in terms of outside influences, like injuries, child-bearing and breast-feeding patterns or belonging to a certain age group or having a certain ethnicity. Later, during the first half of the 20th century, hereditary factors became more important, often discussed with reference to the developing field of genetics. Statistics were part of all these discussions.

They were used for analyzing cancer rates among populations from the mid-19th century and by the first half of the 20th century scientific works on breast cancer usually contained a statistical component. At the same time considerations on cancer risk moved towards a closer emphasis on the natural pathology of the breast and de-emphasized factors originating outside the body, such as the dangers of "civilization" or the impact of trauma. The assumption that estrogen played a part in producing breast cancer became part or the discussion of risk in the first half of the 20th century. It was based on evidence from the laboratory and the clinic: Laboratory experiments in the 1920s showed that tumors could be produced in male mice implanted with ovaries. During the same decade the first clinical study of breast cancer to include both a large group of patients and a control group of healthy women showed that lifetime exposure to estrogen was a significant factor (Jasen, 2002).

3. Environmental risk

The discussions on breast cancer included factors that were conceptualized as lifestyle choices as well as risks that originated in the environment, and on which the individual has no influence. A typical environmental risk factor is radiation. Originally, radioactivity was not considered dangerous (Dommann, 2004; Dry, 2004). It took decades until the damage done especially on doctors and nurses who applied X-rays made it impossible to ignore the dangers associated with radiation. The strategy to deal with these was quantification and standard setting: Based on several months of studies in different X-ray laboratories, the American physicist Arthur Mutscheller identified a dose that does not cause any symptoms. The result was an international standard, the skin-erythema dose of 0.2 roentgen per day. The implicit assumption is that anything below this dose was safe. Determining a tolerance dose in this way is a classic case of risk negotiation in which the danger for doctors, scientists and their employees gets aligned with the requirements of practice.

Subsequently, these negotiations got a new direction. The first important turning point in the assessment of X-rays came in 1927 when the American biologist Hermann Muller (1890–1967) showed that X-rays cause mutations in Drosophila-flies, and that, moreover, the mutation rate increases in a linear pattern with the increase of the X-ray dose. This finding took on a new significance with the dropping of the atomic bomb in August 1945. The Cold War then kept the threat of radiation on the agenda and sensitized the public to its possible dangers, even in civil use, such as for power plants and medical diagnostics. As a consequence, the concept of the "maximum permissible dose" was introduced. The new concept no longer implied the existence of a dose that was safe. Even radiation below a given threshold was deemed to entail a certain risk and should be avoided. In June 1956 the American National Academy of Sciences (NAS) and the British Medical Research Council simultaneously published reports that contained information on the results of studies on survivors of the atomic bomb, patients exposed to high doses of X-rays as part of a therapy, and death rates among radiologists. To determine the standards against which to judge extra, man-made radiation they used the level of normal background radiation. For this purpose the NAS genetics committee provided estimates of the total radiation exposure a person in the United States would be expected to receive over 30 years. They estimated that background radiation caused by cosmic rays and radioactive elements in homes and food accounted for 4.3 r(oentgen) over 30 years. Fallout from weapons testing was estimated between 0.002 and 0.5r over 30 years. Medical X-rays accounted for an additional estimated 3r over 30 years. The NAS report concluded that a dose of 10r, or double background radiation level, would be an acceptable lifetime reproduction (0–30 years) limit. This arbitrary dose was considered to be acceptable because it was allied to a supposedly natural dose, the level of normal background radiation. However, setting a threshold like this entails an internal contradiction: It gives the simultaneous impression of danger – since the organization feels the need to limit exposure – and safety – because the organization assures the citizens that this level of radiation is harmless (Dry, 2004). Above all, the discussions on the risk of radiation demonstrate the essentially political character of any decisions on environmental risk taking, even if they are expressed in technical terms. One can see how reifying potential harm as risk and delegating decisions on it to experts leads to the naturalization of risk. Naturalized risk

appears to simply emerge from technical properties of things instead of power relationships between people (Levidov, 1994: 440–441).

4. Risk factors

Another example of the fact that scientific statements about risk contain and at the same time obscure underlying moral values and implicit political decisions is the emergence of the risk factor concept. Risk factor discourses exemplify how considerations of risk involve the distribution of responsibility (Hilgartner, 1992: 47) because they usually construct 'risk as the consequence of "lifestyle" choices made by individuals, and emphasize the need of self control' (Gabe, 1995: 3). The concept emerged as life insurance companies devised a new statistical approach to predicting chronic diseases for the purpose of selecting policyholders. They identified personal characteristics that increased the probability of premature mortality and required the physicians whom they employed as medical examiners to measure these characteristics. By 1911, life insurance companies had not only determined a number of medical as well as non-medical factors, they had also quantified the statistical risk of excess mortality associated with each. At that stage, those factors included build, family history of diseases, insanity, stroke, premature death of parents and siblings, physical condition, personal and medical history and habits, and occupation. Concerning medical diagnostics, urinalysis and blood pressure measurement proved to be of predictive value (Rothstein, 2003: 50–70, 261). These medical measurements served as a focus for a new, *medical* type of risk factor approach which came to be embodied by the influential Framingham study. This study was initiated in 1947 to survey over a time span of 20 years the population of a typical American city for coronary heart disease (CHD) and its possible causes. Its organizers considered Framingham, a Massachusetts town with a population of 28,000 to be representative of the American urban way of life. The town had been the site of a tuberculosis community study in the interwar years and was located conveniently close to the Boston medical schools. The first Framingham reports were published in 1957 and they claimed that high blood pressure, along with over-weight and hypercholesteremia was associated with the incidence of CHD (Timmermann, 2004).

The Framingham study introduced the life insurance risk factor into medical research, but at the same time changed its character in a number of ways: Whereas the *life insurance* risk factor was conceived in terms of a gradient of risk, depending on its level, *medical* risk factors tended to be dichotomized into healthy and unhealthy levels. Each life insurance risk factor was related to all other risk factors. By contrast, each of the new medical risk factors was usually considered separately. Finally, whereas the life insurance risk factor emphasized both the medical and the social attributes of the applicant, medical risk factors were restricted to medical characteristics (Rothstein, 2003: 279–285). The medicalization of the risk factor approach went even further: Subsequently, risk factors came to be treated as if they were straightforward diseases, especially in the cases of hypercholesteremia and hypertension. Precise quantitative cutoffs and the prescription of a specific drug therapy transformed those conditions into bona fide disease entities (Aronowitz, 1998: 127–141).

Because of its technological character the medical risk factor approach resonates with medical science. It reduces complex social relationships to discrete and measurable physiological phenomena that take place within the individual (even though, ironically, this brand of individualism is rationalized and legitimated by aggregate data and thinking). "The discrete, quantitative contributions of these factors to CHD, the emphasis on specificity and mechanism, and the growing tendency to view risk factors as diseases in their own right, are reductionist features" (Aronowitz, 1998: 112–118, 131–135, quote from p. 112) that link it to the mainstream technocratic approach in medicine (Schlich, 1996). As the approach is being refined, risk factors are becoming ever more specific subproperties of the individual. Genetic research, for example, tries to move beyond broad phenotype characteristics to find the precise gene for diseases like CHD. Risk factors have become a central part of modern clinical, public health and financial strategies for predicting and managing individual variation in disease predisposition and experience. The risk concept is being used as a tool to deal with uncertainty, but a tool that already contains a whole range of political and moral decisions.

5. Risk of medical innovation

The idea of risk is also being applied to medical activity itself. Throughout history, the actions physicians have taken on behalf of their patients have always had a mixture of beneficial and harmful consequences. As the modes of diagnosing and treating disease and illness have become more powerful, they have also grown more dangerous, exposing patients to more potential harm through their anticipated and unanticipated negative consequences (Fox, 2000: 416). Iatrogenic conditions have become a new focus of risk anxiety. The number of articles published on perioperative complications and side effects of drugs has quadrupled between 1986 and 1991 (Skolbekken, 1995: 295–296). Because of those hidden dangers, medical innovation is often perceived as a mixed blessing (Pickstone, 1992; Löwy, 1993). Medicine thus forms part of the general trend in what Ulrich Beck (1986) has characterized as a new phase of modernity which see "progress" increasingly overshadowed by the production of risks.

Again, framing potential dangers in terms of risks entails a particular strategy of dealing with them, implying that the side-effects of medical innovation can be managed in a calculable and controllable manner. This strategy can be seen in the disputes on smallpox inoculation in the 18th century. Smallpox inoculation had its own hazards: Patients could die from it, and they could also spread the disease by infecting others with inoculated smallpox. So the question was whether the benefit outweighed the potential dangers. In England, the physician Thomas Nettleton (1683–1742) introduced a particular approach to this problem, pursuing what he called "Merchants Logick". Merchant's logic argued that physicians should calculate the utility of particular practices by summing up the costs and benefits among a population of patients. Nettleton's was only one of various forms of merchant's logic that cropped up in 18th century medical literature, especially on smallpox inoculation. Most often the numerical arguments balanced profit and loss in terms of public good, which was measured by gross smallpox mortality or the proportion of smallpox mortality to total mortality, and private benefit, measured by the risk of dying from inoculation (Rusnock, 2002: 38–51). The calculation of probabilities in this context is so typical that the discussions on smallpox inoculation, for example those between Daniel Bernoulli and Jean le Rond d'Alembert, are considered classics in the history of probabilistic thinking (Gigerenzer et al., 1989: 17–18).

Another early example of this sort of quantified risk-benefit calculations emerged with the introduction and the selective use of anesthesia in the 1840s, giving rise to what Martin Pernick (1985) described as a "calculus of suffering". Thus, in an article of 1847 the British surgeon and advocate of anesthesia James Simpson embraced the emergent "numerical method" as the best means of setting anesthesia on secure, rational grounds. Medical utilitarians like Simpson could use numerical cost-benefit analysis as a means of objectively managing the "passions and anxieties" provoked by the new technology of anesthesia and construct an "ideology grounded in technical, rationalistic calculation" (Burney, 2004).

In the later decades of the 19th century the acceleration of medical expertise and discoveries gave further impetus to the integration of mathematical statistics with medical research and innovation. After World War II the need for rigorous monitoring and control of therapeutic advances was generally accepted and with the rise of the randomized clinical trial "mathematical statistics came into its own as an accepted regulator of medical research" (Magnello and Hardy, 2002: ix–x). The most important milestone of this development is marked by the reforms of drug regulation in the wake of the thalidomide disaster. In November 1961 the sedative was withdrawn from the market after several thousand children world-wide had been born with incomplete arms and legs, after their mothers had taken thalidomide during pregnancy. As a consequence, governments re-examined the legal mechanisms of drug regulation and long, highly publicized lawsuits followed. Thalidomide turned into a powerful cultural symbol for the risks associated with legal drugs (Timmermans and Leiter, 2004). The incident played a key role in shaping drug regulations in the United States, Germany, and other countries (Daemmrich, 2002; Kirk, 1999). Another drug that reshaped the perception of medication and risk as well the regulatory process for new drugs is the contraceptive pill. Taken for the purpose of preventing pregnancy instead of treating an organic disease, in a sense the pill was the first "life style" drug of the 20th century. Since it was taken by healthy women of reproductive age for long periods

of time the drug raised questions about its potential of harm in terms of fertility and long-term health (Marks, 2001).

6. Risk politics

In whatever context, the risk concept is used to objectify uncertainties. Objectification is achieved by translating the uncertainties into numbers in order to take advantage of their neutralizing effect in situations where values clash and consensus is elusive: "With statistics, hotly debated issues can seemingly be turned into problems to be solved" (Gigerenzer et al., 1989: 236–237). But despite appearances, numerical techniques are not neutral. They embody political decisions on values. The technologically oriented rationale inherent to the statistical approach was criticized from the start: Thus the merchant's logic in the 18th-century debates on smallpox inoculation was rejected by Thomas Dimsdale (1712–1800), an English doctor and advocate of smallpox inoculation. For him, numerical arguments were "unfeeling" und indicative of "reasoning coolly". "Numbers were persuasive because they were impersonal," Andrea Rusnock (2002: 49) writes, 'but, by the same measure, they were also insensitive because they valued the welfare of the population over the welfare of the individual'. In other words, they embodied a population-based, utilitarian approach.

Opposition to population-based reasoning on the basis of a preference for both individual expertise and individualizing clinical practice is a recurring theme in modern medicine. In the early 19th century, Pierre Louis' "numerical method" was rejected by those doctors who saw medicine as being founded on the judgment of the physician dealing with an individual patient in all his or her complexity. Drawing on fundamental disciplinary, philosophical, and political differences, critics feared that Louis' approach threatened the authority of the clinician and his freedom to treat patients on an individual basis (Matthews, 2002: 135–141).

These examples make it clear that statistical reasoning fails to convince those who do not appreciate the generalized type of information it yields. Such fundamental differences in worldviews were part of an "ethical clash" that historians identified also in the 20th century between those doctors who endorsed "professional values centered on the individual" and others who advocated "the statistical necessity of taking averages" (Gigerenzer et al., 1989: 261). Opponents of operative fracture care in the 1960s and 1970s claimed that the potential benefits of the technology did not outweigh the possible harm in the case of complications. Statistical data, they stressed, never predicted the outcome of the individual case nor did they appropriately represent the individual tragedy of complication for the patients who were affected (Schlich, 2002: 121–124). Its critics charged scientific medicine with neglecting the individual character of medical problems, because in order to objectify medicine, treatment procedures must be standardized and treatment results handled in the manner of experimentally derived data. Like in experimental science, a few precisely defined parameters are put into focus and measured in a way that makes them comparable. At the same time, the differences between the individual cases must be played down. As a consequence, the similarities of body parts and their structural lesions get emphasized and the particularities of the patients' individual problems are backgrounded. In his study on early 20th century American medicine Joel Howell (1995: 246) found a general "deep-seated cultural bias in favor of an individual clinician's judgment," amounting to "a fundamental belief that individual clinicians make decisions using information and modes of analysis which simply cannot be captured by any set of formal rules or procedures". Thus, the statistical approach on which risk concepts are based embodies a particular set of choices that have already been made in the moment when dangers get conceptualized as risks. Science is always value-laden: "Although scientific rationality is assumed to be unbiased," Deborah Gordon (1988: 283) explains, "it too is a particular approach to reality, albeit a particularly powerful one, that is as committed to a particular set of values as any other approach. The demand for precision and predictability, the hallmarks of science, are not neutral because certain specific measurements are selected for while other types of information are rendered unimportant or irrelevant." Based on the same assumption, science and technology studies "have attempted to investigate how particular scientific constructions incorporate tacit, closed models of social relationships that are or should be open to negotiation." These models have a normative

dimension, since "scientific knowledge is seen as encoding taken-for-granted norms, commitments, and assumptions that, when deployed in public, inevitably take on a social-prescriptive role" (Wynne, 1995: 362). It is the prescriptive effect of scientific reasoning that turns politically charged issues into problems that can be solved by technical means.

However, the way political problems are translated into technical ones is not always accepted by all those involved. The very act of quantification of "actual risk", for example, necessarily ignores all kinds of qualitative features that may be relevant for the social actors affected, such as the involuntary or unfamiliar character of "exposure" (Levidov, 1994: 442–443). If people reject the translation, scientists tend to patronizingly describe public reactions as "subjective" irrationality. They often ignore the fact that laypeople may have good reasons for their rejection and that the complexity and multidimensional variability of real world problems requires real world rationality rather than statistics (Wynne, 1995). As a rule, these conflicts involve power relationships, they are about the distribution of the burden of uncertainty and about who gets victimized by risks decreed by others (Short, 1992: 10). Disputes on risk decisions thus reflect the conflicting interests and priorities of the different actors involved in a risky activity. This can even mean that laypeople do not care about expert opinion. In the early phase of the contraceptive pill some women were prepared to use it "whatever the costs were to her health". In their individual risk-benefit calculations this was by far the preferable choice. Taking the pill or not is, as Lara Marks (2004: 24) states, "a very individual decision, based on the kind of relationship a woman had, her family circumstances, her medical history and the alternative contraceptives available to her" – all factors that are not part of formal risk-benefit calculations. Another striking example of differing priorities between experts and laypeople is the insistence of severely ill patients to use new drugs even at the risk of grave side-effects, such as those which Steven Epstein (1996) has examined in the case of HIV/AIDS.

7. Historiography of risk in medicine

As these examples show, historical investigation can contribute in a specific way to a better understanding of how people deal with potential health dangers. History thus complements the other approaches investigators have taken to analyze this issue. Researchers with a background in economics first started to analyze risk taking behavior based on the notions of preference and rationality. They were criticized by psychologists who showed that risk decisions are much less predictable than rational choice theory would have it. The psychological approach in turn was censured by sociologists who emphasized the fact that making decision on risks is not just an individual psychological process but a social and relational phenomenon (Clarke, 1992). To this social approach cultural anthropologist added a cultural emphasis exploring "how conflicts over risks can be understood in terms of plural social constructions of meaning which are culturally framed" (Gabe, 1995:7). In their influential essay, Mary Douglas and Aaron Wildavsky (1982:9) state that "questions about acceptable levels of risks can never be answered just by explaining how nature and technology interact. What needs to be explained is how people agree to ignore most of the potential dangers that surround them and interact so as to concentrate only on selected aspects". Risks are exaggerated or minimized according to the social, cultural, and moral acceptability of the underlying activities.

Historical investigation provides the opportunity to do justice to the socially and culturally contingent character of risk realities. Based on the assumption that medical knowledge and practice are products of human activity and that "medicine should be studied simultaneously as a body of knowledge, a practice, a profession, a cultural and social phenomenon and a political issue" (Löwy, 1993: 1–2), historians use concrete case examples to study how risks are being culturally produced in specific periods and places. By revealing "the socially constructed or framed nature of health risks and the various plural rationalities involved", historical studies can contribute to the development of "an alternative to the existing technical approach to risk assessment" (Gabe, 1995:11). This is not a purely academic exercise: an historically informed understanding of decision-making on risks can ultimately offer the background information for finding more effective, more democratic strategies of coping with the insecurities surrounding potential

threats to health, whether they are seen as originating in the environment, individual behavior or in medicine itself.

References

Aronowitz, R. A.: 1998, *Making Sense of Illness. Science, Society and Disease*, Cambridge: Cambridge University Press.

Beck, U.: 1985, *Risikogesellschaft. Auf dem Weg in eine andere Moderne*, Frankfurt: Suhrkamp Verlag.

Burney, I.: 2004, 'Anesthesia and the Evaluation of Surgical Risk in Mid-Nineteenth Century Britain', in Schlich and Tröhler (eds.), *Risks* (forthcoming).

Clarke, L.: 1992, 'Context Dependency and Risk Decision Making', in J. F. Short and L. Clarke (eds.), *Organizations*, pp. 27–38.

Daemmrich, A.: 2002, 'A Tale of two Experts: Thalidomide and Political Engagement in the United States and West Germany', *Social History of Medicine* 15, 137–158.

Dommann, M.: 2004, 'From Danger to Risk: The Perception and Regulation of X-Rays in Switzerland, 1896–1970', in Schlich and Tröhler (eds.), *Risks* (forthcoming).

Douglas, M., and Wildavsky, A.: 1982, *Risk and Culture. An Essay on the Selection of Technological and Environmental Dangers*, Berkeley, Los Angeles, London: University of California Press.

Dry, S.: 2004, 'The Population as Patient: Alice Stewart and the Controversy Over Low-Level Radiation in the 1950s', in Schlich and Tröhler (eds.), *Risks* (forthcoming).

Epstein, S.: 1996, *Impure Science. AIDS, Activism, and The Politics of Knowledge*, Berkeley: University of California Press.

Fox, R. C.: 2000, 'Medical Uncertainty Revisited', in G. L. Albrecht, R. Fitzpatrick and S. D. Scrimshaw (eds.), *Handbook of Social Studies in Health and Medicine*, pp. 407–425. London, Thousand Oaks and New Delhi: Sage.

Gabe, J.: 1995, 'Health, Medicine and Risk: The Need for a Sociological Approach', in J. Gabe (ed.), *Medicine, Health and Risk. Sociological Approaches*, pp. 1–17. Oxford: Blackwell.

Gigerenzer, G., Swijtink, Z., Porter, T., Daston, L., Beatty, J., and Krüger, L.: 1989, *The Empire of Chance. How Probability Changed Science and Everyday Life*, Cambridge: Cambridge University Press.

Hilgartner, S.: 1992, 'The Social Construction of Risk Objects: Or, How to Pry Open Networks of Risk', in Short and Clarke (eds.), *Organizations*, pp. 39–53.

Howell, J. D.: 1995, *Technology in the Hospital. Transforming Patient Care in the Early Twentieth Century*, Baltimore and London: The Johns Hopkins University Press.

Jasen, P.: 2002, 'Breast Cancer and the Language of Risk, 1750–1950', *Social History of Medicine* 15, 17–43.

Kirk, B.: 1999, *Der Contergan-Fall: eine unvermeidbare Arzneimittelkatastrophe? Zur Geschichte des Arzneiwirkstoffs Thalidomid*, Stuttgart: Wissenschaftliche Verlagsgesellschaft.

Levidov, L.: 1994, 'De-Reifying Risk', *Science and Culture* 20, 440–456.

Löwy, L.: 1993, 'Introduction: Medicine and Change', in L. Löwy (ed.), *Medicine and Change: Historical and Sociological Studies of Medical Innovation*, pp. 1–19. Paris: Les editions INSERM.

Magnello, E.: 2002 , 'The Introduction of Mathematical Statistics into Medical Research', in E. Magnello, A. Hardy, (eds.), *Road*, pp. 95–123; 'Preface', in Magnello and Hardy (eds.), *Road*, pp. iii–xi.

Magnello, E. and Hardy, A. (eds.), 2002, *The Road to Medical Statistics*, Amsterdam, New York: Rodopi.

Marks, L. V.: 1991, *Sexual Chemistry. A History of the Contraceptive Pill*, New Haven and London: Yale University Press.

Matthews J. R.: 2002, 'Almroth Wright, Vaccine Therapy and British Biometrics: Disciplinary Expertise Versus Statistical Objectivity', in Magnello and Hardy (eds.), *Road*, pp. 125–147.

Matthews, J. R.: 1995, *Quantification and the Quest for Medical Certainty*, Princeton, NJ: Princeton University Press.

Pernick, M. S.: 1985, *A Calculus of Suffering: Pain, Professionalism and Anesthesia in Nineteenth-Century America*, New York: Columbia University Press.

Pickstone, J. V.: 1992, 'Introduction', in J. V. Pickstone (ed.), *Medical Innovations in Historical Perspective*, Houndmills, Basingstoke: McMillan.

Rothstein, W. G.: 2003, *Public Health and the Risk Factor: A History of an Uneven Medical Revolution*, Rochester: University of Rochester Press.

Rusnock, A.: 2002, '"The Merchant's Logick": Numerical Debates over Smallpox Inoculation in Eighteenth-Century England', in Magnello and Hardy (eds.), *Road*, pp. 37–54.

Schlich, T.: 1996, 'Die Konstruktion der notwendigen Krankheitsursache: Wie die Medizin Krankheit beherrschen will', in C. Borck (ed.), *Anatomien medizinischen Wissens*, pp. 201–229. Frankfurt am Main: Fischer.

Schlich, T.: 2002, *Surgery, Science, and Industry: A Revolution in Fracture Care 1950–1990s*, Basingstoke, Hampshire, New York, Palgrave-Macmillan.

Schlich, T. and Tröhler, U. (eds.), 2004, *The Risks of Medical Innovation: Risk Perception and Assessment in Historical Context*, London, New York: Routledge, (forthcoming).

Short, J. F., Jr.: 1992, 'Defining, Explaining and Managing Risks', in Short and Clarke (eds.), *Organizations*, pp. 3–23.

Short, J. F., and Clarke, L.: 1992a, 'Social Organization and Risk', in Short and Clarke (eds.), *Organizations*, pp. 309–321.

Short, J. F. and Clarke, L. (eds.), 1992b, *Organizations, Uncertainties, and Risk*, Boulder: Westview Press.

Skolbekken, J. -A.: 1995, 'The Risk Epidemic in Medical Journals', *Social Science and Medicine* 40, 291–305.

Timmermann, C.: 2004, 'To Treat or not to Treat: Drug Research and the Changing Nature of Essential Hypertension', in Schlich and Tröhler (eds.), *Risks* (forthcoming).

Timmermans, S., and Leiter, V.: 2004: 'The Redemption of Thalidomide: Standardizing the Risk of Birth Defects,' in Schlich and Tröhler (eds.), *Risks* (forthcoming).

Tröhler, U.: 2000, "*To Improve the Evidence of Medicine*". *The 18th Century British Origins of a Critical Approach*, Edinburgh: Royal College of Physicians of Edinburgh.

Wynne, B.: 1995, 'Public Understanding of Science', in S. Jasonoff, G. E. Markle, J. Petersen and T. Pinch (eds.), *Handbook of Science and Technology Studies*, pp. 361–388. Thousand Oaks, London and New Delhi: Sage.

Department of Social Studies of Medicine
3647 Peel Street, McGill University
Montreal, Quebec
Canada H3A 1X1
E-mail: thomas.schlich@mcgill.ca