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Acquisition and Application of New Medical Knowledge by Anesthesiologists:

Three Recent Examples

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Studies of dissemination of innovations in medical practice can help us understand the communication of new medical findings and improve the quality and cost-effectiveness of medical care. This study describes and analyzes dissemination of three medical findings and associated changes in clinical practice among 354 anesthesiologists in Massachusetts. The three findings dealt with potential hazards of subanesthetic concentrations of anesthetic gases (Item 1), problems caused by diffusion of nitrous oxide into body cavities (Item 2), and increased blood loss during therapeutic abortion with halothane anesthesia (Item 3).

Nearly all anesthesiologists who responded to the survey were aware of these findings, but patterns of dissemination were quite different. For Item 1, but not for Items 2 or 3, there was marked acceleration in spread of awareness following initial publication of the findings. By 1976, 17 of every 20 anesthesiologists for whom the findings were relevant had changed practice because of Items 1 and 3, but only 13 of 20 had changed in response to Item 2. The average delay between awareness and change in practice was much greater for Item 1 than for Items 2 and 3.

Journal articles were a dominant source of information only for Item 1. For all items, continuing education courses were a source of information significantly less often than were colleagues or published papers. Anesthesiologists were equally likely to change practice in response to a new finding whether they learned the information from published papers, colleagues or continuing education courses. Board-certified anesthesiologists tended more than others to rely on papers, and younger anesthesiologists tended more than the older to be influenced by information from colleagues. (Key words: Anesthesiologists; Education.)

NEW SCIENTIFIC KNOWLEDGE takes time to become incorporated into medical practice. Implementation of new practices requires that the physician become aware of new findings, be persuaded of the value of a change in practice, adopt the practice and retain it. The process usually begins with publication of new findings in a medical journal, but a physician may learn from other sources. Physicians differ in their assessment of new findings and vary in their readiness to adopt changes in practice. A fuller understanding of the utilization of medical innovations would seem useful, whether one wants to speed implementation of desirable practices or retard the adoption of undesirable ones.

In this paper, we describe and analyze how awareness of three medical findings and associated changes in practice developed among anesthesiologists in Massachusetts. The three findings were as follows.

Item 1. Several medical problems (spontaneous abortion, renal and hepatic disease, cancer) are more common in anesthesia and operating room personnel than in comparable control groups. This suggests that exposure to subanesthetic concentrations of anesthetics may be hazardous to the health of medical personnel.[1–3]

Item 2. Nitrous oxide diffuses into gas-filled body cavities more rapidly than nitrogen diffuses out. Because this can produce an increase in gas volume in obstructed bowel or an increase in gas pressure in pneumothorax or during pneumoencephalography, nitrous oxide should be avoided or used with caution under certain circumstances.[4–7]

Item 3. During anesthesia for therapeutic abortion, blood loss has been shown to be significantly greater when halothane is used than when other anesthetics are used.[8]

These findings were selected because they met the following criteria:

a. They appeared to be firmly established.
b. They seemed sufficiently important to the practice of anesthesiology to have clear implications for change in practice.
c. Enough time had elapsed since their discovery to permit implementation patterns to emerge.

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d. For each finding, we believed we could identify the first published source commonly available to American anesthesiologists.[1-4,8]

Beyond these criteria, selection of findings was arbitrary. We did not intend our survey of awareness and application of these findings to measure appropriateness of anesthesiology practice.

Methods

Early in 1976 we mailed to the 631 physician members of the Massachusetts Society of Anesthesiologists a four-page questionnaire designed to gather information on the educational habits of anesthesiologists; how and when they might have learned about the selected findings; whether and when that information was incorporated into their practice. We asked respondents about the means they customarily use to keep abreast of advances in their specialty: number of hours per week spent reading journals; number of hours per month spent at teaching conferences in anesthesiology; number of hours during the previous year spent at meetings or continuing education courses dedicated to anesthesiology; other educational activities, as specified by the respondent.

We asked respondents to try to recall when they first became aware of each of the three findings or to indicate that they had not been aware of the finding before reading the questionnaire. When respondents had been aware, we asked whether and when they had changed practice by beginning to scavenge waste gases for Item 1, to avoid nitrous oxide in the presence of trapped gas for Item 2, and to avoid halothane for anesthesia during abortion for Item 3. When respondents were aware of the item but had not changed practice, we asked whether they doubted the veracity of the finding and whether it was relevant to their practice. Respondents were further asked to specify sources through which they had learned about the items: published papers, continuing education courses, discussions with colleagues, or other channels specified by the respondents. When respondents had changed practice, we asked them to indicate how influential each source of information had been. We conducted a second mailing to non-respondents six weeks after the initial survey.

Responses were encoded on punch cards and tabulated by digital computer. We tallied the number of respondents for whom each finding was relevant (Nr), the number who received information from each channel of communication (Nc) and the number influenced to change by the channel (NΔc). NΔc indicates those who designated a channel "very" or "moderately" influential in their decision. The *power* of a channel, that is, its effectiveness as a source of information leading to change in practice, may be defined as NΔc/Nr. The *penetration* ratio for a channel, its ability to reach anesthesiologists, may be defined as Nc/Nr. The *persuasion* ratio, how well the information convinced the anesthesiologists, is given by NΔc/Nc. Thus defined, the power of a channel is the product of penetration and persuasion ratios: NΔc/Nr = Nc/Nr × NΔc/Nc. The maximum power that could be achieved by a channel of communication for a given finding would be the same as the ratio of the number of anesthesiologists who changed practice to the number for whom the finding was relevant.

Responses for each of the three items are summarized as curves representing development of awareness and change in practice among all respondents. We also tabulated delay between awareness and change for each respondent who had changed practice and calculated for each item the fraction whose delay after awareness was less than one year, between one and three years, between three and five years, and longer than five years. Relations of individual characteristics of respondents with changes in practice and with reliance upon different sources of information were tested for significance by chi-square analysis or by difference in proportions.

Results

The questionnaire was returned by 354 physicians, 56 per cent of the survey population. A few respondents failed to complete all parts of the questionnaire. One hundred eighty-one (51 per cent) were certified by the American Board of Anesthesiology, 18 (5 per cent) had foreign certification equivalent to that of the American Board, 67 (19 per cent) were eligible for Board examination and 50 (14 per cent) were residents in training. Ninety-two per cent of respondents devoted nine-tenths or more of their time to the practice of anesthesiology, and 58 per cent spent nine-tenths or more of their time taking care of patients. Eighty-one per cent of respondents graduated from medical school after 1949, and the annual increment entering practice remained fairly constant from 1949 through 1974. Respondents tended to be more recent graduates than non-respondents and more often were board certified (fig. 1).

Respondents reported spending an average of 3.4 hr/wk reading anesthesiology journals, 7.6 hr/mo attending teaching rounds and conferences, and about 24 hours in continuing education courses during the previous year. Thirty-five respondents (10 per cent) volunteered that they regularly listened to educational cassette tapes, averaging about 2 hr/wk.

At the time of our survey, almost all respondents

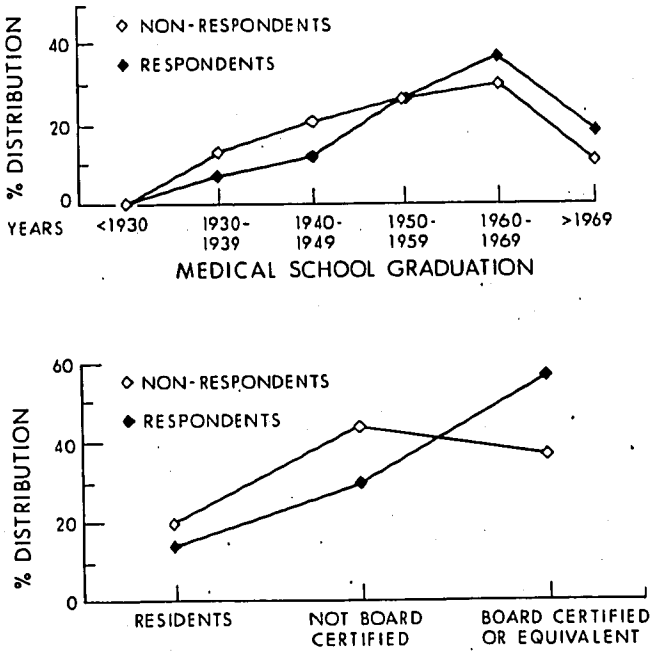

FIG. 1. Comparison of respondents and non-respondents. Information for non-respondents was obtained from the Massachusetts Society of Anesthesiologists.

were aware of the three findings, and fewer than 5 per cent of those aware questioned the validity of any of the findings. A substantial proportion of respondents (23 per cent) said the findings for Item 3 were not relevant, presumably because they do not administer anesthesia for abortions.

The annual growth in awareness among respondents unaware at the beginning of each year was most rapid for Item 1 and most gradual for Item 3 (fig. 2). There appeared to be a distinct acceleration in the spread of awareness after initial publication of specific findings for Item 1, but a relation between first publication and awareness rate for Items 2 and 3 was less evident (fig. 2). The development of awareness and change in practice among all respondents is shown in figure 3 for Item 1, figure 4 for Item 2 and figure 5 for Item 3.

Figure 6 depicts delay between becoming aware and changing practice. These data are not evident from figures 3–5, because some physicians who became aware early were not the first to change practice, while some who became aware later changed practice more rapidly. Delay between awareness and change was much greater for scavenging waste gases than for the other innovations. Only 23 per cent of those who instituted scavenging did so within one year of learning of the hazards of subanesthetic concentrations of anesthetics (Item 1). By contrast, changes in practice regarding nitrous oxide (Item 2) and halothane (Item 3) were initiated within one year by 78 and 88 per cent of respondents, respectively.

Dates of graduation and board certification of individual physicians, and hospital size, as reflected by the number of staff anesthesiologists, were not related to change in practice or to delay between awareness and change ($P > 0.10$).

Table 1 depicts power, penetration and persuasion ratios for published papers, discussion with colleagues, and continuing education courses. There were wide differences in the extents to which anesthesiologists were reached through different channels (penetration ratio), but persuasiveness of information conveyed by different channels (persuasion ratio) was impressively uniform for each item. Anesthesiologists were most readily persuaded to change by Item 3 and least readily persuaded by Item 2, regardless of how they learned of the finding. Continuing education courses were least often given as a source of information for all items. Published papers and colleagues were about equally likely sources for Items 2 and 3, while published papers were a dominant source of information for Item 1.

With the exception of reading anesthesia journals, greater exposure to a channel of communication was associated with a greater likelihood of influence through that channel. Anesthesiologists influenced by colleagues, compared with those who were not, spent 60 per cent more time in conferences and worked in hospitals where the anesthesia staff was twice as large, on average. Anesthesiologists influenced by

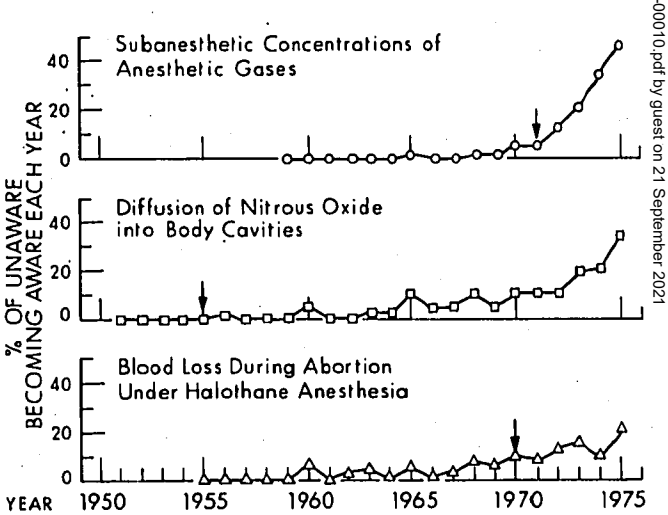

FIG. 2. Growth in awareness of new findings among respondents who were unaware at the beginning of each year. Arrows point to years marking the first publication commonly available to American anesthesiologists.

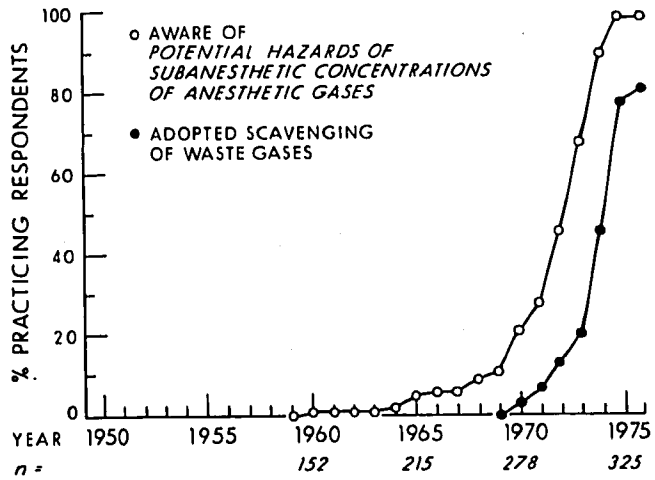

FIG. 3. Diffusion of awareness and change in practice for Item 1.

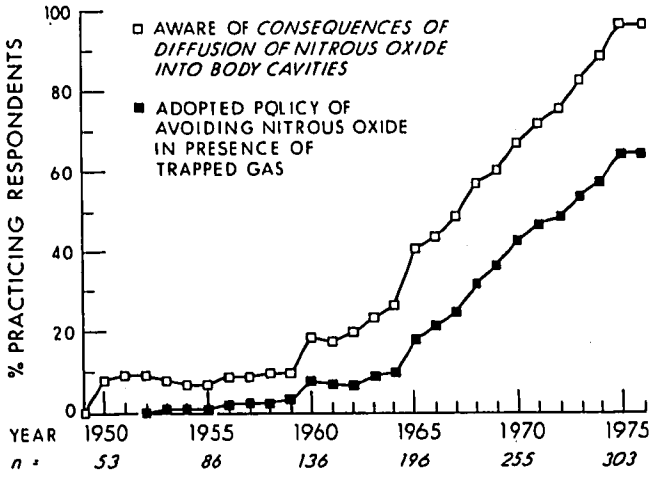

FIG. 4. Diffusion of awareness and change in practice for Item 2.

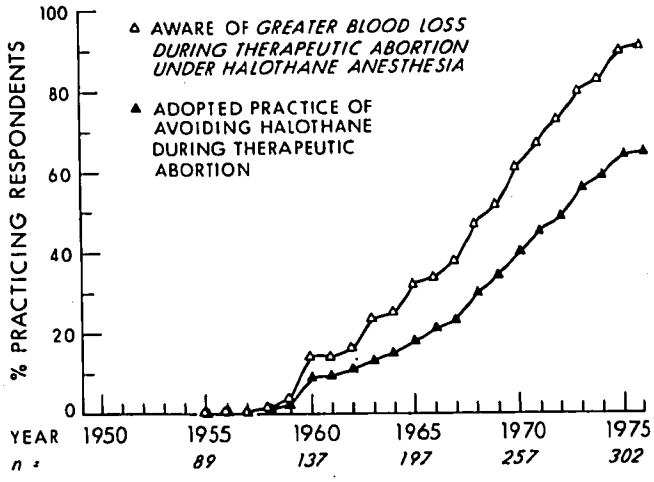

FIG. 5. Diffusion of awareness and change in practice for Item 3.

continuing education courses spent 50 per cent more time in such pursuits. By contrast, the average time spent reading anesthesia journals was the same for those influenced by published papers as for those who were not.

Published papers were listed as an influential source of information for a higher proportion of board-certified (84 per cent) than board-eligible anesthesiologists (72 per cent) or other respondents (58 per cent) ($P < 0.01$). Degree of certification was not associated with differential reliance on colleagues or continuing education courses ($P > 0.10$). Eighty-one per cent of respondents who graduated from medical school since 1965 were strongly or moderately influenced by colleagues, compared with only 70 per cent of those graduating earlier ($P < 0.01$). Continuing education courses were least often reported as a source of influential information ($P < 0.01$), but were more likely to be influential for those who graduated before 1965 (48 per cent) than for later graduates (32 per cent) ($P < 0.01$).

Some respondents mentioned educational cassette tapes, textbooks, reports in the popular press, and personal experiences as other sources of influence on changes in practice. For Item 1 we inquired specifically whether hospital policy influenced the anesthesiologist's decision to scavenge waste gases. Hospital policy influenced 28 per cent of those scavenging and was more likely to influence residents in training than other anesthesiologists ($P < 0.01$).

Discussion

Results of this study are based upon responses to a questionnaire returned by about half of those to whom it was sent. This raises the possibilities of sample bias and faulty recollection among respondents. Those who recognized the selected findings were probably more likely to return the questionnaire than those who did not, which is suggested by the higher response rate from board-certified than other anesthesiologists (fig. 1). Self-selection may be responsible for the apparent absence of association between decisions to change practice and physician characteristics of board certification and graduation date. Still valid, however, are differences in patterns of dissemination for the three findings and associated changes in practice, differences in delay between awareness and change for the three items, and comparative effectiveness and reliance upon various sources of information.

Spreads of awareness over time differed among the three items (fig. 2). For Item 1, there was rapid increase in awareness following the article by Cohen *et al.* in 1971 showing that a group of anesthetists

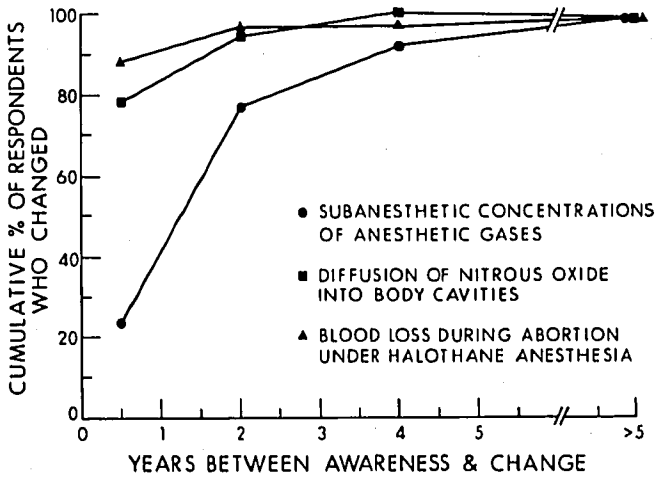

FIG. 6. Delay between awareness of findings and change in practice. Data were grouped into four classes (≤1, 1–3, 3–5, and ≥5 yr) and are plotted at the midpoints for the first three classes.

had a substantially higher incidence of spontaneous abortion than controls.[1] Similar findings had been previously reported in Russia in 1967[9] and in Scandinavia in 1970.[10] In marked contrast is the more gradual spread of awareness of Item 2. In 1955, Hunter reported on cardiovascular problems due to diffusion of nitrous oxide into artificial pneumothorax,[4] but this article apparently produced little appreciation of the risk. Reports of Eger and Saidman in 1965 describing problems with nitrous oxide during pneumoencephalography and with obstructed bowel[5,6] had little immediate effect on awareness.

Dissemination of Item 3 was even more gradual than that of Item 2, with fewer than 20 per cent of the previously unaware becoming aware during any year before 1975 (fig. 2). Knowledge regarding blood loss from the gravid uterus had unfolded over more than a decade. As early as 1958 excessive uterine bleeding was reported to accompany the use of halothane for vaginal delivery or cesarean section.[11] In 1962, however, light halothane anesthesia was said not to lead to excessive blood loss during vaginal delivery,[12] and in 1969 blood loss during removal of retained products of conception was said to be no greater with halothane than when other anesthetics are used.[13] Despite such conflicting views, only one respondent felt that the findings in Item 3 were not convincingly documented, and 91 per cent reported awareness that halothane is associated with increased blood loss during therapeutic abortion. The article by Cullen *et al.*, in 1970,[8] an explicit report upon which Item 3 was based, seemed to have had no impact on rate of awareness of the finding among anesthesiologists.

Four types of variables may explain differences in rates and extents of dissemination of new medical practices and differences in delays between awareness and change:

1. Characteristics of innovations themselves.
2. Characteristics of physicians who may become aware of information and adopt new practices.
3. Characteristics of channels of communication.
4. Characteristics of the process for deciding whether to adopt or reject the innovation.

The characteristics of the innovation that matter

TABLE 1. Effectiveness of Channels of Communication

	Channel of Communication	Persuasion Ratio*	Penetration Ratio*	Power*	Fraction of Maximum Power*† (Per Cent)
Item 1: Subanesthetic concentrations of anesthetic gases	Papers	0.85	0.91	0.78	94
	Colleagues	0.82	0.78	0.64	77
	Continuing education courses	0.83	0.53	0.44	53
Item 2: Diffusion of nitrous oxide into body cavities	Papers	0.73	0.71	0.52	80
	Colleagues	0.75	0.73	0.55	85
	Continuing education courses	0.79	0.39	0.31	48
Item 3: Blood loss during abortion with halothane anesthesia	Papers	0.93	0.66	0.61	72
	Colleagues	0.93	0.70	0.65	76
	Continuing education courses	0.93	0.33	0.31	36

* These indices are defined in the text.

† Maximum power, as discussed in the text, would be 0.83 for Item 1, 0.65 for Item 2 and 0.85 for Item 3.

are those perceived by the potential adopter, such as relevance to practice, advantages over existing alternatives, compatibility with experience, ease of use, opportunity to observe results of others, and ability to undertake a limited trial.

By 1976, 17 of every 20 respondents were scavenging gases, and a similar proportion of those participating in abortions had discontinued use of halothane anesthesia for that procedure, but only 13 of 20 respondents had abandoned use of nitrous oxide in the presence of trapped gas. A large number of anesthesiologists may have discounted the importance of diffusion of nitrous oxide or felt its advantages outweighed any drawbacks.

Scavenging is the only change that does not necessitate relinquishing previous practice, and is also the only one with potential direct benefits to operating room personnel. Risk from repeated exposure to low concentrations of anesthetics also fits with other evidence linking occupational exposure to chemical agents with mutagenesis, teratogenesis and carcinogenesis.[14] Adverse consequences of nitrous oxide anesthesia in the presence of trapped gas and increased blood loss with halothane anesthesia are probably equally observable; both are more readily observed than the long-term risk of subanesthetic concentrations of anesthetics.

If use of scavenging ultimately disseminated most widely, it also showed the longest average delay between awareness and change in practice. The decision to change anesthetics for certain procedures, the type of change measured with Items 2 and 3, may be accomplished immediately by the individual. By contrast, the decision to install and use scavenging equipment entails a collective decision-making process and institutional action that would introduce a lag between decision for and implementation of change. Forty-five per cent of those who had not instituted scavenging did advise pregnant personnel to avoid the operating room, suggesting an appreciation of risk. We did not examine organizational behavior for this innovation, but such studies have been carried out for other innovations in health care.[15,16]

Published papers might be expected to be the major direct source of information about new medical findings. Papers do dominate communication of Item 1, but colleagues appear to be at least as important as publications for Items 2 and 3. It is interesting to compare the importance of channels over and above published papers: only 6 per cent of the power of communication for Item 1 may be attributed exclusively to colleagues and continuing education courses, but 20 and 28 per cent for Items 2 and 3, respectively, may be ascribed to channels other than papers.§

Papers assume relatively more prominence as sources of information for board-certified anesthesiologists. Physicians who are inclined to learn from written sources might be more likely to pursue certification. Also, preparing for certification may encourage physicians to rely upon medical journals as primary sources of medical knowledge.

The relatively small influence of continuing education courses may result either from limited appeal or from limited availability. A sizable minority of respondents are attracted by the convenience of cassette tapes as an alternative to formal teaching sessions.

Awareness and utilization of innovations have been studied in fields as diverse as anthropology, agriculture, economics, communication, education, sociology and marketing, as well as medicine.[17] Most studies of the attitudes and behavior of physicians toward innovations have been with regard to new drugs.[18–22] Pharmaceutical companies have a particular interest in learning the most efficient and effective means of convincing physicians to adopt new prescription drugs, but many other medical practices profoundly affect the cost and quality of care without necessarily involving commercial interests. The medical community places great emphasis on the importance of careful clinical research to produce new medical knowledge. The process by which that knowledge is disseminated and put into practice is also worthy of attention.

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§ The redundancy of additional channels with published papers may be measured by the ratio $Power_{PP}/Power_{Max}$, where $Power_{PP}$ is the power of published papers for that item, and $Power_{Max}$ is the maximum power possible for the item (*i.e.*, the ratio of the number who change practice to the number for whom the item is relevant). The fraction of power that may be attributed exclusively to channels other than published papers is then given by $1-Power_{PP}/Power_{Max}$ for each item.

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