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Risk for Serious Gastrointestinal Complications Related to Use of Nonsteroidal Anti-inflammatory Drugs

A Meta-analysis

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■ *Objective:* To describe the relative risk for serious gastrointestinal complications due to nonaspirin nonsteroidal anti-inflammatory drug (NSAID) exposure among NSAID users as well as in selected subgroups.

■ *Design:* Overview and meta-analysis.

■ *Data Identification:* A literature search of English-language studies examining the association between NSAIDs and adverse gastrointestinal events for the period 1975 to 1990 identified using MEDLINE and communicating with three internationally recognized experts.

■ *Data Analysis:* A qualitative summary of study characteristics and a critical appraisal of study quality were done. The results of 16 primary studies were selected and combined statistically. Summary estimates were weighted by sample size and quality score.

■ *Main Results:* The overall odds ratio of the risk for adverse gastrointestinal events related to NSAID use, summarized from 16 studies (9 case-control and 7 cohort) was 2.74 (95% CI, 2.54 to 2.97). The summary odds ratios were as follows: elderly patients, (aged ≥ 60 years), 5.52 (CI, 4.63 to 6.60); patients under 65 years of age, 1.65 (CI, 1.08 to 2.53); women, 2.32 (CI, 1.91 to 2.82); and men, 2.40 (CI, 1.85 to 3.11). The summary odds ratio for NSAID users receiving concomitant corticosteroids compared with NSAID users not receiving corticosteroids was 1.83 (CI, 1.20 to 2.78). The summary odds ratio for the first gastrointestinal event was 2.39 (CI, 2.16 to 2.65). The relative risk for a subsequent or unspecified gastrointestinal event was 4.76 (CI, 4.05 to 5.59). The summary odds ratio for less than 1 month of NSAID exposure was 8.00 (CI, 6.37 to 10.06); for more than 1 month but less than 3 months of exposure, the summary odds ratio was 3.31 (CI, 2.27 to 4.82); and for more than 3 months of exposure, the summary odds ratio was 1.92 (CI, 1.19 to 3.13).

■ *Conclusions:* Users of NSAIDs are at approximately three times greater relative risk for developing serious adverse gastrointestinal events than are nonusers. Additional risk factors include age greater than 60 years, previous history of gastrointestinal events, and concomitant corticosteroid use. Another possible risk factor is the first 3 months of NSAID therapy. The risk for serious gastrointestinal events appears to be equal among men and women. These data represent summary statistics from 16 studies and cannot be considered generalizable to all NSAID users.

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Nonsteroidal anti-inflammatory drugs (NSAIDs) are the most widely used agents for the treatment of musculoskeletal and arthritic syndromes (1). Use of these agents has been increasingly associated with gastrointestinal toxicity, including mild dyspepsia, as well as more serious gastrointestinal reactions such as bleeding, perforation, and other events leading to hospitalization or death. Although researchers agree that an increased risk for gastrointestinal toxicity exists with NSAID use, the size of the reported risk has varied markedly, and there is little agreement on the definition of "high risk" groups (2-19).

We reviewed the literature on NSAID-related adverse gastrointestinal events. First, we summarized study characteristics and appraised study quality. We then did a meta-analysis of all controlled trials that examined the risks for serious gastrointestinal events among NSAID users. Our primary objective was to estimate a summary odds ratio or relative risk for serious gastrointestinal complications due to nonaspirin NSAID exposure.

Methods

A comprehensive search of the English-language literature from 1975 to 1990 was conducted using MEDLINE and searching the following terms: anti-inflammatory agents, non-steroidal; gastropathy, toxicity, adverse effects, or side effects; peptic ulcer or dyspepsia; gastric erosion, gastritis, gastric ulcer, gastric mucosa, endoscopy; and human. We also searched for specific NSAIDs by name.

Five hundred twenty-six references were obtained. These were reviewed by one of the authors, and any citation that mentioned NSAID-related gastrointestinal events was selected (Figure 1). One hundred forty-two articles met this criterion and were entered into "Reference Manager" (20). Five additional articles were identified by communication with three investigators (Marie Griffin, MD; Michael Langman, MD; and Richard Hunt, MD) from the United States, United Kingdom, and Canada, respectively. These 5 articles were added to the data set, for a total of 147 articles.

From the 147 articles in the data set, 40 studies were selected that examined the association between NSAIDs and adverse gastrointestinal events. Specific inclusion and exclusion criteria were applied to these studies independently by two of the authors. All studies that contained a comparison group and provided an estimate of risk for serious gastrointestinal complications (defined as bleeding, perforation, or other adverse gastrointestinal events resulting in hospitalization or death) in NSAID users compared with nonusers, regardless of underlying disease, were included in the meta-analysis. A study was excluded if its primary objective was to assess effectiveness, if it involved the treatment of children (under 18 years of age), if it described fewer than ten patients, if the only NSAID studied was salicylate, or if the outcome examined was

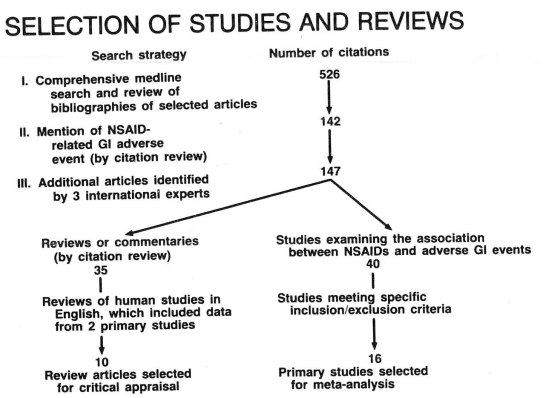

Figure 1. Selection of studies and reviews.

the identification of ulcer rather than the presence of serious gastrointestinal complications. Disagreements between the two reviewers were resolved by consensus. Sixteen studies were selected (21-36) for meta-analysis (*see* Figure 1).

Meta-analysis

The following criteria were used to evaluate the quality of the studies included in the meta-analysis: blinding, definition of outcome, case selection, control selection, matching technique, definition of exposure, and control for confounders (Appendix A). The Methods section of each study was photocopied, with care taken to exclude any mention of the authors' names, study results, or journal title. Study quality was evaluated in a blinded fashion by two of the investigators. Quality scores were assigned to each criterion according to its relative importance. A quality score of 0 indicated poor definitions and no attempt to avoid bias, and a score of 46 indicated the converse. The average score (between the two readers) among the first six categories constituted the baseline score for the study. For every 5 confounders identified in a primary study, 1 bonus point was awarded, to a maximum of 5 points for studies that identified more than 25 confounders. Thus, the maximum quality score attainable was 51. Agreement between the two readers regarding the quality score was evaluated using the kappa statistic (37).

Data from all articles were abstracted in duplicate to avoid errors. The two observers met, discussed each item, and resolved all disagreements and errors. A final copy of the completed data collection forms was then created and entered into a database (ORACLE, Oracle Corporation, Belmont, California) (38).

The results of the 16 primary studies were combined statistically using two different techniques. First, overall point estimates of the odds ratios and 95% confidence intervals (CIs) were calculated from the raw data of the 16 selected studies using the Mantel-Haenszel statistic (39). The second technique involved combining the published odds ratios and CIs directly across studies to produce an overall estimate of the odds ratio and 95% CI (40). The latter will hereafter be referred to as the "direct" method. The direct method was the primary statistical analysis technique used, and all results were calculated using this method unless otherwise stated.

The purpose of this analysis was not to estimate a common parameter, but rather to compute an average or summary statistic across the 16 selected studies. The CI for this statistic cannot, therefore, be generalized beyond the study samples. All summary estimates were weighted by sample size. The influence of the quality scores on the summary estimates was evaluated using logistic-regression analysis with quality score as a covariate.

Overall odds ratios for all studies included in the meta-analysis as well as odds ratios for various subgroups were calculated. The overall odds ratios referred to the odds ratios combined from the main research questions of each of the studies. Summary odds ratios for various subgroups were calculated from those studies which provided data on these subgroups. The method of Breslow and Day was used to test for homogeneity of the Mantel-Haenszel estimates (41). Tests of homogeneity were also performed for the direct method according to the method of Greenland (40).

Results

We selected 16 studies (9 case-control and 7 cohort) that specifically examined the risks for clinically defined, NSAID-related, adverse gastrointestinal events (21-36). The reported relative risks varied from 1.0 (34) (indicating no increased risk for gastrointestinal events) to 13.7 (29) (indicating a risk for NSAID users 13.7 times greater than that for nonusers). Two potential sources of variability were identified: differences in study characteristics and differences in study quality.

Study Characteristics

Study characteristics are shown in Appendix B. For both the case-control and cohort studies, serious gastrointestinal events were defined among hospital-based cases. Among the case-control studies, the ascertainment of gastrointestinal outcome was not done in a uniform manner. Gastrointestinal events were assessed based on the results of endoscopy, roentgenography, or surgery (27-29, 33, 35) or on a clinical diagnosis of hematemesis or melena (26, 30-32). Some case-control studies used community controls (31, 33, 35); others compared cases with hospital controls (28-30, 32) or used both types of controls (26, 27). Most studies matched controls directly with cases (26-28, 30, 31, 33). Two case-control studies used a nested case-control

Table 1. Study Quality Scores

Study (reference)	Baseline (range, 0-46)*	Bonus (range, 0-5)†	Total (range, 0-51)
Griffin et al. (33)	25.5	4.00	29.5
Levy et al. (32)	24.5	5.00	29.5
McIntosh et al. (35)	22.5	5.00	27.5
Somerville et al. (26)	22.5	4.00	26.5
Bartle et al. (27)	23.0	3.00	26.0
Henry et al. (30)	20.5	2.00	22.5
Jick et al. (31)‡	20.0	1.00	21.0
Carson et al. (24)‡	15.5	5.00	20.5
Guess et al. (25)‡	16.0	3.00	19.0
Bloom (22)‡	14.5	4.00	18.5
Beard et al. (23)‡	14.5	4.00	18.5
Beardon et al. (21)‡	13.5	2.00	15.5
Armstrong and Blower (29)	14.5	0.00	14.5
Collier and Pain (28)	13.5	1.00	14.5
Jick et al. (34)‡	10.0	2.00	12.0
Alexander et al. (36)	9.50	1.00	10.5

* Baseline scores were assigned based on an evaluation of the following design items: explicit definitions of exposure, outcome, case and control status as well as the use of blinding and matching.

† Bonus points were assigned based on the number of confounders, which were accounted for in the analysis. *See* text for method of bonus-point assignment.

‡ Cohort studies.

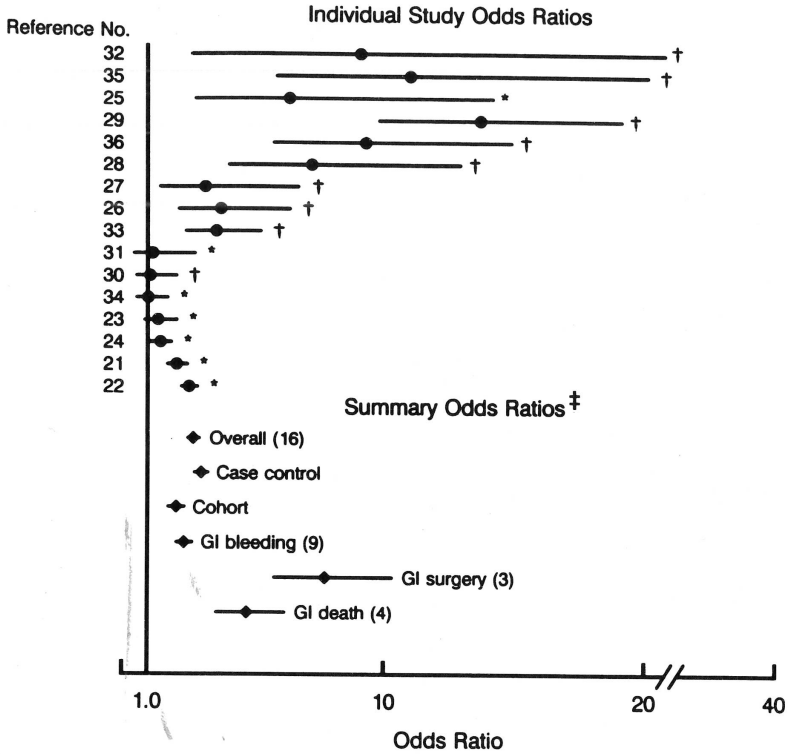

Figure 2. Individual study and summary odds ratios. Individual study odds ratios are arranged in order of increasing sample size (top to bottom). Individual study odds ratios were provided in the original studies (21-28, 30-32, 34, 36) or calculated from data provided in original studies (29, 33, 35). (●, Individual study odds ratio; ◆, summary odds ratio; the 95% confidence intervals are indicated by the extended lines; * cohort study; † case-control study; ‡ odds ratios summarized by "direct" technique [40]; numbers in parentheses are the number of studies combined.)

design (31, 33). Determinations of NSAID exposure were made by an unblinded review of clinical notes (28-30), a structured questionnaire with interviewers who were blinded (26, 27, 32, 35), or an extraction of prescription data from pharmacy computer files (31, 33). In all cohort studies, the assessment of NSAID exposure was based on prescription files. Estimates of the duration of NSAID exposure varied from 30 days (24, 25) to 90 days (22, 23, 31, 34). One cohort study (25) examined deaths from gastrointestinal causes, whereas the remainder looked at hospitalizations caused by gastrointestinal complications. Samples examined in the cohort studies included the Group Health Cooperative in Puget Sound; the Pennsylvania Medicaid group; the residents of Saskatchewan, Canada; and the residents of the Tayside Region, Scotland. The Puget Sound Group Health Cooperative represents a younger, employed population, the Medicaid group is elderly, and the Tayside and Saskatchewan groups represent residents of geographically diverse districts.

Study Quality

Table 1 shows the study quality scores. Methodologic assessment of the 16 studies showed acceptable agreement between two observers for the six study quality categories evaluated (mean kappa, 0.70; minimum, 0.56; maximum, 0.83). The mean kappa for the quality category of blinding was 0.67 (minimum, 0.0; maximum, 1.0); for case selection, 0.75 (minimum, 0.66; maximum, 0.90); for control selection, 0.68 (minimum, 0.4; maximum, 1.0); for definition of exposure, 0.74 (minimum, 0.59; maximum, 0.96); for matching technique, 0.83 (minimum, 0.66; maximum, 1.0); and for definition of outcome, 0.56 (minimum, 0.0; maximum, 1.0). Disagreements regarding control of confounders were reexamined and resolved by consensus. The six studies with the highest quality scores were case-control studies (Table 1). These studies gave more explicit definitions of cases, controls, and exposure and used blinding more frequently. The study quality score was not found to be a significant covariate in the regression model ($P > 0.2$).

Summary Odds Ratios

Published odds ratios and summary odds ratios from the primary studies are shown in Figure 2. The overall odds ratio of the risk for adverse gastrointestinal events related to NSAID use (summarized from 16 case-control and cohort studies) is 2.74 (CI, 2.54 to 2.97). The summary odds ratio (combined from 8 studies) for elderly persons is 5.52 (CI, 4.63 to 6.60). In the cohort studies, the term "elderly" refers to persons 65 years of age or older. In the case-control studies, "elderly" refers to persons 60 years of age or older. The summary odds ratio for nonelderly persons, combined from 3 studies, is 1.65 (CI, 1.08, 2.53). These data show a greater than threefold increase in relative risk for serious gastrointestinal events among elderly NSAID users when compared with nonelderly users.

Odds ratios were subdivided by gastrointestinal out-

Table 2. Comparison of Summary Odds Ratios and Confidence Intervals Obtained by Two Methods

Category	Number of Studies Combined	Summary Odds Ratio	95% CI
Overall	12*/16†	2.86*/2.74†	2.62 to 3.12*; 2.54 to 2.97†
Patient ≥ 60 years of age	6/8	6.24/5.52	5.21 to 7.48; 4.63 to 6.60
Patient < 60 years of age	2/3	3.07/1.65	1.62 to 5.82; 1.08 to 2.53
Gastrointestinal bleeding	7/9	2.71/2.39	2.26 to 3.24; 2.11 to 2.70
Gastrointestinal surgery	3/3	7.04/7.75	5.34 to 9.29; 5.83 to 10.31
Gastrointestinal cause of death	3/4	4.22/4.79	3.24 to 5.50; 3.64 to 6.22
Unspecified adverse gastrointestinal event	2/3	2.68/1.79	2.42 to 2.98; 1.70 to 1.90

* Mantel-Haenszel technique for case-control studies only.
† Direct technique method of Greenland (reference 40).

come. The odds ratio for gastrointestinal bleeding, combined from nine studies, was 2.39 (CI, 2.11 to 2.70). The odds ratio for gastrointestinal surgery, combined from three studies, was 7.75 (CI, 5.83 to 10.31). The summary odds ratio for gastrointestinal death, combined from four studies, was 4.79 (CI, 3.64 to 6.22). Thus, the relative risk for surgical or fatal outcomes among NSAID users is 2- or 3-fold higher than the relative risk for gastrointestinal bleeding.

The summary odds ratio for women was 2.32 (CI, 1.91 to 2.82), whereas the summary odds ratio for men was 2.40 (CI, 1.85 to 3.11). The summary odds ratio for women compared with men was 1.15 (CI, 0.89 to 1.50). These data do not support gender as an independent risk factor. The risk for first compared with subsequent gastrointestinal event was also examined. The summary odds ratio for the first gastrointestinal event, combined from six studies, was 2.39 (CI, 2.16 to 2.65). The relative risk for subsequent or unspecified gastrointestinal event, combined from the remaining 10 studies, was 4.76 (CI, 4.05 to 5.59). These data suggest that patients with a history of gastrointestinal events may have an increased relative risk for further events. The use of concomitant corticosteroids was also examined. The summary odds ratio for NSAID users receiving concomitant corticosteroids compared with NSAID users not receiving corticosteroids was 1.83 (CI, 1.20 to 2.78). This finding suggests an approximately twofold increase in the relative risk among NSAID users who are receiving corticosteroids compared with NSAID users not receiving corticosteroids.

Summary odds ratios were also obtained using the Mantel-Haenszel statistic. A comparison of the results obtained by the two statistical techniques showed that the direct method enabled the use of data from more studies, resulting in narrower CIs. Summary odds ratios by both methods were similar in most categories (Table 2).

Summary odds ratios calculated according to individual NSAID used and duration of NSAID exposure were as follows: piroxicam, 11.12 (CI, 6.19 to 20.23); indomethacin, 4.69 (CI, 2.97 to 7.41); aspirin, 3.38 (CI, 2.26 to 5.01); naproxen, 2.84 (CI, 1.68 to 4.82); and ibuprofen, 2.27 (CI, 1.85 to 2.80). There is substantial overlap in the CIs among NSAIDs. The duration of NSAID consumption may be related to the size of the odds ratio (Figure 3). The summary odds ratio for less than 1 month of NSAID exposure was 8.00 (CI, 6.37 to 10.06); for longer than 1 month but less than 3 months, 3.31 (CI, 2.27 to 4.82); and for longer than 3 months, 1.92 (CI, 1.19 to 3.13). The highest odds ratios were obtained from studies in which the duration of NSAID consumption was less than 1 month.

Data were also subdivided by gastrointestinal event and age (Table 3). The relative risk for gastrointestinal surgery for nonelderly individuals, combined from three studies, was 0.44 (CI, 0.29 to 0.66), whereas the risk for gastrointestinal surgery among elderly persons, combined from three studies, was 10.42 (CI, 7.40 to 14.66). These data suggest a tenfold increase in relative risk for gastrointestinal surgery among elderly users when compared with younger users.

Estimates of the prevalence of serious gastrointestinal events among NSAID users were summarized from four cohort studies (7, 23, 25, 34). The summary, 1-year prevalence among NSAID users was 1 per 1000; the prevalence among elderly users (≥ 65 years of age) was 3.2 per 1000; and the prevalence among younger users (< 65 years of age) was 0.39 per 1000.

Sources of Heterogeneity

Tests for homogeneity were statistically significant ($P < 0.05$) for all analyses, indicating that the differ-

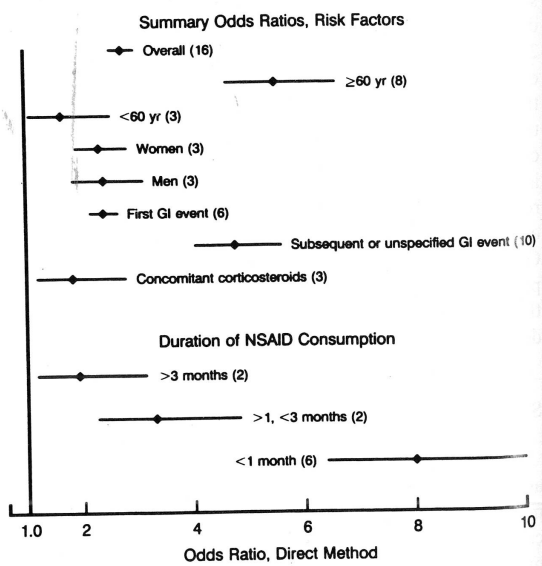

Figure 3. Summary odds ratios and risk factors. (◆, Summary odds ratio; the 95% confidence intervals are indicated by the extended line; numbers in parentheses are the number of studies combined.)

ences among the results of individual studies are greater than can be expected on the basis of chance alone.

We did two different types of analyses to identify sources of heterogeneity. Heterogeneity across studies is composed of intrastudy heterogeneity and inter-study heterogeneity. In an effort to describe intra-study heterogeneity, tests of homogeneity were conducted for several subgroups across studies. These subgroups were subdivided according to gastrointestinal outcome, age, age and gastrointestinal outcome, and use of individual NSAIDs. Each of these subgroups accounted for a portion of the variability, thus reducing the test statistic for homogeneity. There was, however, no subgroup identified that accounted for most of the observed heterogeneity. In an effort to describe interstudy heterogeneity, we did a multivariate regression analysis using the log of the study odds ratio as the dependent variable and study design, duration of NSAID use, gastrointestinal outcome, and average age as the independent variables. The regression was weighted using the individual study variances. The four independent variables accounted for approximately half of the interstudy variability.

Discussion

Two research designs have been used to study the risk for gastrointestinal events related to NSAID therapy: retrospective cohort and case-control studies. Most of the cohort studies used secondary analysis of health insurance registries in which data were collected primarily for billing purposes. The computerized case definition for gastrointestinal events is subject to substantial misclassification (42-44). Misclassification rates of up to 29% were noted in studies using retrospective chart review to confirm computerized diagnoses (23, 31, 34), resulting in contamination of the case group by controls and of the control group by cases and thus reducing the relative-risk estimate. Similarly, the information on NSAID exposure obtained from these registries may not have been of optimal quality. The duration of NSAID exposure is often unknown and assumptions are made from prescription registries regarding the average duration of NSAID use. Some studies estimated an average prescription duration of 90 days with full patient compliance (23, 31, 34). Such an assumption may overestimate the duration of NSAID exposure, biasing the results toward a falsely low relative risk. The frequency of NSAID use in a study sample determines the power of that study to detect a statistically significant relative risk (45). Nonsteroidal anti-inflammatory drug use among patients with prepaid health plans may be lower than that of the general population, further underestimating the relative risk. These factors contribute to the lower relative risks reported by the cohort studies when compared with the case-control studies.

In two case-control studies, different techniques were used to determine NSAID exposure among case patients and controls (28, 29). Physicians hospitalizing patients with gastrointestinal bleeding are more likely to inquire about NSAID use than are physicians questioning controls or their relatives. Such differences in the determination of NSAID exposure bias the results toward a falsely large relative risk. The use of a structured interview administered by an investigator who is blinded to the status (case patient or control) of the patient results in more valid estimates of relative risk (17, 26). Well-designed, nested, case-control studies minimize the selection bias, inherent in hospital-based case-control studies (33).

Although there have been many studies examining the gastrointestinal risks of NSAID use, important methodologic limitations and differences in study characteristics contribute to the conflicting results. Retrospective cohort studies probably underestimate the relative risk, whereas some case-control studies probably overestimate it. The aggregation of the results from observational studies is controversial (46). The strongest studies are those that defined cases, controls, outcome, and exposure accurately and reproducibly (26, 27, 32, 33, 35), as reflected by the quality-assessment scores in this meta-analysis (Table 1).

We conducted a structured overview of all previous reviews of NSAID-related adverse gastrointestinal events. The quality of the 10 reviews selected (3, 6-12, 18, 19) was assessed according to several criteria: the comprehensiveness of the literature search, the minimization of bias in the selection of primary studies, the assessment of the quality of the primary studies, the appropriateness of the techniques used in data synthesis, and the validity of the conclusions made by the authors as supported by the data. Most of the published reviews on this topic cite only a portion of the available literature, do not provide a critical assessment of the quality of the studies cited, and fail to combine the results of these studies statistically. Only 1 of the 10 reviews used a clearly defined, comprehensive search strategy (6). Inclusion criteria were stated for 2 of the 10 reviews (6, 8). A quality assessment of the studies was done in only 1 review (6). Appropriate, explicitly stated methods of data synthesis were given in only 2 reviews (6, 19).

Table 3. Subgroup Odds Ratios Combined from Case Control and Cohort Studies Using the "Direct" Method*

Variable	Number of Studies Combined	Summary Odds Ratio	95% CI
Gastrointestinal event by age*			
< 60 years			
Gastrointestinal bleeding	1	1.03	0.60 to 1.76
Gastrointestinal surgery	3	0.44	0.29 to 0.66
≥ 60 years			
Unspecified gastrointestinal adverse event	3	1.78	1.69 to 1.87
Gastrointestinal bleeding	9	2.38	2.10 to 2.69
Gastrointestinal surgery	3	10.42	7.40 to 14.66
Gastrointestinal cause of death	4	4.40	3.35 to 5.79

* Gastrointestinal events occurring in hospitalized patients.

Meta-analysis is a systematic, quantitative, strategy of reviewing and summarizing data from the literature to address a specific research question. It differs from the traditional review article in that it uses explicit inclusion and exclusion criteria, incorporates a standardized quality assessment, and provides a quantitative estimate of effect size. In this way, meta-analysis reduces the potential for error and bias implicit in the traditional review article (47).

Meta-analyses have been criticized for their emphasis on statistical techniques and their lack of attention to critical descriptions of methodologic and substantive issues discussed in the individual studies. The "best-evidence synthesis" method combines the strengths of quantitative meta-analytic techniques with detailed, qualitative analysis of study characteristics typical of traditional review articles (48). We have examined critically the study characteristics and quality and have provided a quantitative summary of the relative risks.

Because meta-analysis is a retrospective form of research, it is limited by any biases inherent in the primary studies. As with any review article, meta-analysis is subject to the preferential selection of studies demonstrating significant results (49). This publication bias is most problematic in studies of effectiveness in which it is assumed that studies showing no effect are less attractive to publishers and, therefore, remain unpublished. Such bias is less likely in studies of risk, in which the protective effect of an exposure on health status is of equal interest as the negative effect. Studies showing a protective effect of NSAIDs on the gastrointestinal mucosa would be of great interest. Studies showing no risk for gastrointestinal complications associated with NSAIDs would also be of interest. Using the data from the 16 studies in this overview, we determined that it would require having missed approximately 300 studies showing no gastrointestinal effect of NSAIDs to bring the summary odds ratio to unity. We believe such a scenario to be unlikely.

An assumption underlying most meta-analyses is that of homogeneity, the belief that differences among studies are due to sampling variation alone (50). Statistical tests for homogeneity examine systematic differences among study results depending on study characteristics. The statistical power of these tests depends on the sum of study sample sizes. In this meta-analysis, studies of large samples were combined, resulting in a sample size of approximately 1.7 million persons. Under these circumstances, statistical tests for homogeneity have a large amount of power to detect relatively modest heterogeneity. In this meta-analysis, tests for homogeneity were significant, suggesting important heterogeneity among these studies. Our results, therefore, cannot be considered generalizable to the overall sample of NSAID users. Rather, they represent summary statistics for the distribution of odds ratios in the selected studies.

Data from the primary studies were combined using two different methods: the Mantel-Haenszel statistic and the "direct" method (39, 40). The Mantel-Haenszel statistic is the most widely used meta-analysis technique (47). When compared with the Mantel-Haenszel statistic, the direct method has the advantage of retaining the standardization, stratification, and regression modeling used in the calculation of the odds-ratio estimates in the individual studies. This technique also allows the inclusion of studies in which the raw data were not published. Finally, this technique has the advantage of allowing the combination of odds ratios from case-control and cohort studies. For these reasons, the direct method may provide a more accurate estimate of the true overall odds ratio.

Summary data from 10 studies showed an inverse relation between the duration of NSAID consumption (estimated from prescription registries) and the relative risk for serious gastrointestinal events, suggesting that the period of greatest risk occurs during the first 3 months of NSAID therapy. This finding, which has recently been confirmed by others (51), may result from gastric mucosal adaptation: Endoscopic studies have shown that gastric mucosal damage lessens with continued aspirin therapy (52, 53). This relation, however, could be confounded by rates of compliance, because compliance with NSAID therapy, and thus exposure, is likely to be greatest early in the course of therapy.

One-year prevalence estimates were summarized from four cohort studies with varying durations of exposure (30 days to 1 year) by assuming that the risk for serious gastrointestinal events remained constant for 1 year. If, as the above data suggest, the risk is greatest during the first 3 months of therapy, this assumption would result in an overestimate of the true 1-year prevalence of NSAID-related gastrointestinal events. Alternatively, the methodologic limitations of the cohort studies suggest that an underestimate of the true risks for gastrointestinal events related to NSAID use may exist.

In summary, we conclude that NSAID users are at approximately three times greater relative risk than nonusers for developing serious adverse gastrointestinal events. Additional risk factors suggested by this analysis were age greater than 60 years, previous history of gastrointestinal events, concomitant corticosteroid use, inclusion in the first 3 months of NSAID therapy, and possibly use of piroxicam. Gender was not found to be an independent risk factor. Further studies are needed that provide an accurate estimate of the absolute risk for NSAID-related adverse gastrointestinal events and that examine the risk factors for such events.

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Appendix A. Study Quality Assessment Data Collection Form

Blinding				
Blinded assessment of eligibility of cases and controls	Yes	No	Unknown	
Blinded assessment of outcome	Yes	No	Unknown	
Blinded assessment of exposure	Yes	No	Unknown	
Definition of outcome				
Death due to gastric or duodenal ulcer defined surgically, endoscopically, by x-ray, or at autopsy				
Hospitalization due to gastric or duodenal ulcer defined by endoscopy or surgery				
Death or hospitalization due to gastric or duodenal ulcer defined or confirmed by chart review				
Hematemesis or melena defined by chart review				
Other				
Outcome defined as:				
First gastrointestinal event				
Any gastrointestinal event				
Unspecified				
Case selection				
Source of cases:				
All persons with disease in a defined segment of the population				
Medical care facility				
Health insurance registry				
Was computerized case definition verified by chart review?	Yes	No	Unknown	NA
Was there adjustment for case misclassification?	Yes	No	Unknown	NA
Control selection				
Source of controls				
Community				
Hospital				
Registry				
Unknown				
Sampling of controls				
Random				
Nonrandom				
Unknown				
Matching technique				
Were controls matched to cases?	Yes	No	Unknown	
What was the case-control ratio?				
1:1				
1:2-6				
1:> 6				
Unspecified				
NA				
Exposure				
Was duration of NSAID exposure defined?	Yes	No	Unknown	
NSAID use determined by:				
Direct patient inquiry or questionnaire				
Chart review				
Pharmaceutical registry				
Unknown				
Was NSAID use determined in the same manner for cases as for controls?	Yes	No	Unknown	NA
Was computerized ascertainment of exposure verified by chart review?	Yes	No	Unknown	NA
Was there adjustment for misclassification of exposure?	Yes	No	Unknown	NA
Control for confounders				
Aspirin use	Yes	No	M*	Unknown
Prednisone use	Yes	No	M	Unknown
Age	Yes	No	M	Unknown
Multiple NSAID use	Yes	No	M	Unknown
Past history of ulcer	Yes	No	M	Unknown
Past history of gastrointestinal bleeding	Yes	No	M	Unknown
Alcohol use	Yes	No	M	Unknown
Smoking	Yes	No	M	Unknown
Duodenal ulcer	Yes	No	M	Unknown
Health status	Yes	No	M	Unknown
Medical surveillance	Yes	No	M	Unknown
Anticoagulant use	Yes	No	M	Unknown
Sex	Yes	No	M	Unknown
Socioeconomic class	Yes	No	M	Unknown
Antacid or H_2-blocker use	Yes	No	M	Unknown
Indication for NSAID	Yes	No	M	Unknown

* M = measured but not used in the analysis; NA = not available.

Appendix B. Characteristics of Studies Used in the Meta-analysis*

Reference	Case Selection	Control Selection	Ascertainment of Exposure	Definition of Outcome
(35)†	Patients with bleeding gastric ulcer seen at outpatient endoscopic centers, Sydney, Australia; 1982 to 1985 (n = 63)	Randomly selected from Sydney electoral rolls (n = 411)	Telephone interview Structured questionnaire	Endoscopically proven gastric ulcer; hemorrhage-active bleeding or black clot at endoscopy, or hematemesis or melena
(28)†	Patients hospitalized for perforated peptic ulcer, Cambridge, England; 1973 to 1982 (n = 269)	Patients admitted for surgical emergencies, age and sex matched, etc. (n = 269)	Retrospective note review in cases. Not measured in controls, estimated by Intercontinental Medical Statistics for United Kingdom (1977 to 1982)	Perforation diagnosed by surgery, radiography, or necroscopy
(27)†	Consecutive patients hospitalized with non-variceal upper gastrointestinal bleeding, Toronto, Canada; 1982 to 1983 (n = 57)	Hospitalized patients and visitors, age and sex matched, visited physician within 2 months (n = 123)	Prospective interview	Hematemesis or melena on admission; all examined by endoscopy
(26)†	All patients (≥ 60y) hospitalized for bleeding peptic ulcer, Nottingham, England; 1983 to 1985 (n = 230)	Hospitalized controls without peptic ulcer; (n = 230); community controls (n = 230); age, sex, and general practice matched	Structured questionnaire, single interviewer	Clinical diagnosis of hematemesis or melena
(29)†	Consecutive patients who died or required emergency surgery for bleeding or perforated peptic ulcer, Cheshire, England; 1983 to 1985 (n = 235)	Hospitalized patients without peptic ulcer, unmatched (n = 1246)	Review of admitting physician note and direct patient questioning in cases. Direct questioning of controls or their relatives	Diagnosis by autopsy, endoscopy, or surgery
(30)†	Hunter Health Statistics Unit patients who died after peptic ulcer complication, New South Wales, Australia; 1980 to 1986 (n = 80)	Hunter Health Statistics Unit patients who survived bleeding or perforated peptic ulcer; matched for age, sex, ulcer site, and nature of complication (n = 160)	Review of clinical notes during week of admission	Diagnosis from database verified by chart review
(31)†	Group Health Cooperative (GHC) patients hospitalized for peptic ulcer perforation, Puget Sound, Washington (n = 54)	GHC controls matched for age, sex, and date of entry into plan (n = 324)	GHC pharmacy computer files	Diagnosis of perforation confirmed by review of discharge summaries
(32)†	Patients hospitalized for hematemesis or melena, U.S., Canada, and Israel; 1977-1984 (n = 57)	Patients hospitalized for conditions judged to be independent of antecedent analgesic use (n = 2417)	Trained nurse interviewer (cases and controls)	Diagnosis of hematemesis or melena by discharge summary
(33)†	Tennessee Medicaid patients (≥ 65y), death due to gastric or duodenal ulcer; 1976-84 (n = 122)	Tennessee Medicaid patients (≥ 65 years of age); stratified random sample, matched for age, sex, race, and nursing home status (n = 3897)	Medicaid formulary	Gastric or duodenal ulcer confirmed by surgery, endoscopy, or autopsy
(34)‡	GHC members ≥ 65 years who received an NSAID prescription for ≤ 90 d, 1977 to 1982	GHC members ≥ 65 years who did not receive an NSAID prescription	GHC prescription files	Hospitalizations for gastritis, bleeding peptic ulcer or hematemesis identified by computerized ICD codes
(23)‡	GHC members < 65 years who received an NSAID prescription for ≤ 90 d	GHC members < 65 years who did not receive an NSAID prescription	GHC prescription files	Hospitalization for gastritis, bleeding peptic ulcer or hematemesis identified by computerized ICD codes

Appendix B. Characteristics of Studies Used in the Meta-analysis*

Reference	Case Selection	Control Selection	Ascertainment of Exposure	Definition of Outcome
(31)‡	GHC members who received an NSAID prescription for ≤ 90 d, 1977 to 1983	GHC members who did not receive an NSAID prescription	GHC prescription files	Hospitalization for upper gastrointestinal perforation identified by computerized ICD codes confirmed by discharge summaries
(24)‡	Medicaid group, Michigan and Minnesota patients who received an NSAID prescription ≤ 30 d, 1980	Medicaid patients, Michigan and Minnesota patients who did not receive an NSAID prescription	Computerized pharmaceutical files	Upper gastrointestinal bleeding identified by Medicaid billing diagnoses, not verified by chart review
(25)‡	Saskatchewan Health Plan patients who received an NSAID prescription ≤ 90 d, 1983	Saskatchewan Health Plan patients matched for exposure time who did not receive an NSAID prescription	Saskatchewan drug formulary	Fatal upper gastrointestinal bleeding or perforation identified by computerized ICD codes, discharge summaries, and autopsy reports reviewed; misclassifications eliminated
(22)‡	Pennsylvania Medicaid population, patients who received an NSAID prescription ≤ 90 d, 1984-85	Pennsylvania Medicaid population matched for time of exposure who did not receive an NSAID prescription	Computerized Medicaid prescription files	Diagnoses of gastric, peptic, or duodenal ulcer and related conditions identified by computerized ICD codes, not verified by chart review
(21)‡	Users of one of five NSAIDs obtained from Prescription Pricing Division, Edinburgh, Tayside Region, Scotland, March-October 1983	NSAID nonusers in the Prescription Pricing Division, matched for age, sex, and general practitioner	Prescription files	Hospitalizations for gastrointestinal events identified by computerized ICD codes, not verified by chart review

* ICD = International Classification of Diseases; GHC = Group Health Cooperative of Puget Sound; NSAIDS = nonsteroidal anti-inflammatory drugs.
† Case-control studies.
‡ Cohort studies.

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