

SPINE SECTION (RESEARCH)

Pressure-Controlled Lumbar Discography in Volunteers Without Low Back Symptoms

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ABSTRACT

Background. For lack of a criterion standard for lumbar discogenic pain, the validity of lumbar discography cannot be determined directly. The false-positive rate of discography, however, can be inferred from the prevalence of positive responses in asymptomatic volunteers. Responses in normal volunteers have been reported in only three studies, and the prevalence of positive responses has been “occasionally, zero, and 10%.” None of these studies, however, controlled for both pressure of injection and intensity of response.

Purpose. To determine the prevalence of positive responses to lumbar discography in asymptomatic volunteers, controlled for pressure of injection and intensity of response.

Study Design/Setting. Prospective, observational study, conducted in a private spine center.

Patient Sample. Four lay persons and nine physicians underwent lumbar discography, with manometry.

Outcome Measures. The prevalence of painful responses were tabulated in terms of the intensity of response, the pressure of injection, the segment stimulated, disc morphology, and past history of low back pain.

Results. Some 56% of discs were not painful, despite maximum pressurization. The remaining 44% of discs were painful, to various degrees, at various pressures. Most discs required high pressures of injection to be painful but even so, were only mildly painful. A receiver–operator curve was derived to demonstrate combinations of pain intensity and pressure below which the probability of a response was zero or less than 10%.

Conclusions. Lumbar discs in asymptomatic volunteers can be made painful, but as a rule, the pain is mild and requires high pressures of injection. If attention is paid to pressure of injection and intensity of response, operational criteria can be defined that provide lumbar discography with a potential false-positive rate of zero or less than 10%.

Key Words. Prospective; Observational; Discography; Discogram; Spine; Lumbar; Manometry; Pressure; Asymptomatic Volunteer; False-Positive; Prevalence

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Introduction

There can be no doubt that lumbar intervertebral discs can hurt. They are endowed with the necessary innervation to be a source of pain [1–3]. They are known to be painful under natural and artificial conditions. Among naturally occurring conditions, discitis is mercifully rare, but the pain it produces can be excruciatingly intense [4]. Under artificial conditions, probing lumbar discs in conscious patients undergoing laminectomy produces pain [5–7]; and injecting discs with contrast medium reproduces pain in patients undergoing diagnostic studies [8–23]. What is controversial is not whether or not discs can hurt but how lumbar discogenic pain can be diagnosed.

At present, discography is the only available means for diagnosing lumbar discogenic pain. It is, however, a provocation test, for it requires reproduction of the patient's pain by stressing the disc with an injection of contrast medium. As it is a provocation test, discography inherits the two major liabilities of all provocation tests. The response may be dependent on the intensity of the provocation stimulus, and the response, being subjective, may be confounded by factors other than the intensity of the stimulus.

Since its introduction in 1948 [24], lumbar discography was practiced without regard to operational criteria. For several decades, practitioners did not stipulate how strongly discs should be stimulated when tested; nor did they stipulate how severe the evoked pain should be in order for the test to be considered positive. By implication, any painful response to a stimulus of any intensity could be regarded as constituting a positive response.

This state of affairs was taxonomically unsound. Discography requires unambiguous operational criteria. A limit to the intensity of stimulation is required, in order to avoid the potential liability that any disc can be made to hurt if it is stimulated strongly enough. A threshold for intensity of response is required, lest a trivial level of pain be wrongly regarded as indicating that the disc tested is responsible for the patient's accustomed pain.

For a test to be valid, one requirement is that it has a low rate of false-positive responses, preferably zero. By convention, the false-positive rate is determined by comparing the results of the test with those of a criterion standard [25]. This facility, however, is not available for discography, for there is no known criterion standard for discogenic pain, apart from discography itself.

Nevertheless, an estimate of the possible false-positive rate can be obtained by determining how often the test is positive in asymptomatic volunteers. If the test is never positive in such volunteers, operators can be confident that it is unlikely to be false-positive in patients. On the other hand, if the test is positive in normal volunteers, operators can be warned that the false-positive rate will be nonzero in patients.

Several studies have provided various results on how often lumbar discography is positive in asymptomatic volunteers. Massie and Stevens [26] reported that discography was "only occasionally" positive in their volunteers. Walsh et al. [27] found no discs to be painful in any of their 10 volunteers, and credited the test to have 100% specificity. Carragee et al. [28], however, reported contrary data. They claimed that 10% of their 10 volunteers had at least one painful disc. The available data on lumbar discography in normal volunteers are therefore conflicting. However, they are also confounded by other variables.

The subjects in the study of Carragee et al. [28] were significantly younger than those of Walsh et al. [27]. Those of Massie and Stevens [26] were not described. Carragee et al. [28] recorded and reported the pressure of injection, while Walsh et al. [27] recorded pressures but did not report them. Massie and Stevens [26] did not report pressures. Walsh et al. [27] required a pain score of at least 5 out of 10 for a positive response, and Carragee et al. [28] used the same criterion. The study of Massie and Stevens [26] predated the use of either the visual analog scale or numerical pain rating scale in pain research, and used neither.

The present study was undertaken in the effort to resolve persisting controversy concerning lumbar discography. Not only was discography performed in normal volunteers, but also the results were stratified for differences in intensity of stimulus and severity of response, and for disc morphology.

Methods

The study was approved by the Institutional Review Board of Quorum Review, Inc. No remuneration was provided for participating. In order to be eligible, subjects had to have no allergies to contrast media, iodine, or cephalosporin antibiotics; and were able to undergo magnetic resonance imaging (MRI) scanning. All subjects were informed of the nature of the study and the risks

of discography, before consenting to participate. All were required to obtain or to provide an MRI scan of their lumbar spine taken within the last 6 months

Initially, 16 volunteers were recruited, but three were found to have a history of greater than three episodes of low back pain in the previous year, and were excluded as not representing asymptomatic individuals. The remaining sample of 13 consisted of nine men and four women, with a mean age of 46.5 years (range: 33–61). The sample consisted of four lay individuals and nine physicians, recruited from among the staff, friends, and colleagues of the investigators. The volunteers were selected from these sources because they already had insights into the relative safety of discography, and trusted the investigators who were to perform the procedure. Physicians, in particular, were enrolled for the additional reason that they could describe accurately the intensity, distribution, and nature of any pain they experienced.

Discography was performed in a surgical suite, under aseptic conditions, by one of three discographers, who, respectively, had 5, 25, and 30 years of experience with the procedure. Intravenous antibiotics (2 g of cephalosporin) were administered 20 minutes prior to the procedure. All subjects were premedicated with 0.025 mg/kg midazolam prior to the procedure. A few participants were given a minimal dosage (1–2 mL) of propofol during needle insertion. Throughout the procedure, subjects were monitored with pulse oximetry and a blood pressure cuff. Supplemental oxygen was administered by nasal cannula.

Prior to injection, a fluoroscopic examination of the spine was performed to confirm the segmentation and to identify the segments to be tested. Using a standardized technique, at least three levels between L1–2 to L5–S1 were tested in each subject. Using a posterolateral approach, a 20-gauge, 3.5-inch introducer needle was advanced to the surface of the target disc. Through the introducer needle, a 25-gauge, 6-inch needle was passed into the center of the disc, and its position confirmed with Anterior Posterior (AP) and lateral fluoroscopic imaging. Nonionic contrast medium mixed with 6 mg/mL cephalosporin was injected into each disc at 0.05 cc/second using a controlled injection syringe with digital pressure readout (Intellisystem, Merit Medical Systems, South Jordan, UT).

At the time of disc injection each subject was awake, alert, and able to respond to instructions or questions. They were asked to report the nature

and location of any pain evoked during the procedure, and to rate its intensity on a 0–10 numerical pain rating scale.

The opening pressure was recorded when contrast medium was first seen to enter the disc. As each subsequent 0.5 mL of contrast medium was injected, both the static and dynamic pressures of injection, the location of contrast medium, and any pain response were recorded. The intradiscal pressure was defined the dynamic pressure minus opening pressure (psi a.o.; pounds per square inch above opening pressure). Injection was continued until one of the following end points was reached: the subject experienced pain that they rated as having a severity of at least 5; or intradiscal pressure reached 80–100 psi a.o.; or a total of 3.5 mL of contrast medium had been injected. In some cases, the final pressure of injection exceeded 100 psi a.o. because the pressure rose rapidly during the final few seconds of injection.

When each injection was terminated, AP and lateral spot films were obtained to record the distribution of contrast medium. When all levels had been tested in a given subject, computerized tomography was performed of all those levels.

The primary outcomes were the incidence of pain and its severity when any disc was stimulated, and the intradiscal pressure when injection was terminated. To corroborate a pain response or its absence, all subjects were videotaped throughout the procedure. Three examiners subsequently reviewed the videotape of each procedure and scored it for pain behavior, using the Modified Wong-Baker FACES rating and verbal expression rating scale [29,30]. Each of these instruments rates pain behavior on a 0–4 scale, on which 0 indicates no pain behavior, and 4 indicates maximum pain behavior. When all three examiners agreed on their rating, the agreed score was entered. When examiners disagreed, they viewed the videotape again until a consensus score was achieved. The score reported in the results was the sum of the scores on the two rating scales.

Fleeting responses, such as a burst of pain, lasting only one or less than a few seconds, were not accepted as positive. Such responses ostensibly can occur when fissures suddenly open, and the disc is subject to a rapid but brief surge of pressure whose magnitude cannot be measured. For a disc to be considered painful, the response to disc stimulation had to be sustained. The evoked pain had to persist for a period of at least 30 seconds, and be associated with a sustained, static pressure of measurable magnitude.

Primary outcomes were stratified for past history of pain and for disc morphology, as seen both on MRI before discography and on computed tomography (CT) after discography. For history of low back pain, subjects were stratified into two groups: those with no history of low back pain, and those with occasional low back pain, being no more than two episodes of low back pain in the previous year. The mean ages for these two groups were 48.6 (range: 38–61) and 44.2 (range: 33–61), respectively, and did not significantly differ statistically. Of the seven subjects with no low back pain, three were lay persons and four were physicians. Of the six subjects with occasional low back pain, one was lay.

The magnetic resonance images of each disc tested were graded for signal intensity using a I to V scale for disc degeneration [31]. The CT discograms were graded 0, 1, 2, 3, for the presence and extent of radial fissures according to the Dallas discogram scale [32].

Results

Discography was successfully performed in 43 discs in the 13 subjects. In all but three subjects discography was performed at L3–4, L4–5, and L5–S1. In those three subjects, we elected not to perform discography L5–S1 because of sacralization or spondylolisthesis of L5. In two of those subjects, however, discography was additionally performed at L1–2 and L2–3. In one other subject, who tolerated the procedures well, discography was additionally performed at L2–3. No complications occurred in any subjects. With respect to incidence of pain, intensity of response, and injection pressure, the physician volunteers did not differ demonstrably from the lay volunteers.

The responses to disc stimulation varied between individuals, between groups, and according to the segments stimulated (Table 1). Only one of the seven discs at L1–2 and L2–3 (14%) was painful, and two of 13 L3–4 discs (15%); but nine of 13 L4–5 discs (69%), and seven of 10 L5–S1 discs (70%) were painful. In those subjects with no history of back pain, 12 of 23 discs were painful (52%). In those with occasional low back pain, 7 of 20 discs (35%) were painful. Three patients with a history of occasional back pain recognized the pain that they experienced at discography was concordant with their familiar pain.

There was no relationship between the MRI appearance of a disc and whether it was painful or not (Tables 2 and 3). Nor was there any correla-

tion between pain and the Dallas discogram rating (Tables 2 and 3). Although nearly all discs that were painful had a grade 3 annular tear, an equal number of such discs were not painful (Table 4). The only evident anatomical correlate was that discs were more likely to be painful at L4–5 and L5–S1 than at L1–2, L2–3, or L3–4 (Tables 1 and 2).

Although many discs were painful, the intensity of the pain evoked varied considerably, as did the pressure of injection when pain occurred. Of the 19 painful discs, 11 were first painful at pressures of injection of 20, 30, or 40 psi a.o., whereas eight required pressures in excess of 50 psi a.o. before being painful (Table 4). Meanwhile, 10 discs were pressurized to over 100 psi a.o. without any onset of pain. The intensity of pain was rated as zero in 24 discs, and 3 or less in 12 discs (Table 5). Four discs scored 4, and two discs scored 5 on the numerical pain rating scale. Only three subjects exhibited pain behaviors. In all cases these were minor, and occurred at high pressures of injection. No pain behaviors were evident in any of the other subjects, including those who reported concordant reproduction of their pain.

From the data obtained, the cumulative probability of a disc being painful, at a particular intensity, could be tabulated according the pressure of injection at the time at which pain was evoked. In constructing this table, it was assumed that if a subject experienced pain at a particular pressure, they would also have experienced pain at higher pressures; and if a patient rated their pain at a particular intensity, they would also have rated their pain at lower intensities. The probabilities of experiencing pain were essentially similar for subjects with no history of low back pain and those with occasional low back pain (Table 6).

In both groups, the probability of experiencing pain increased as pressure of injection increased, but the intensity of pain tended to be low (Table 6). No subject experienced pain of intensity 6, and only one experienced an intensity of 5. At any given pressure, the probability of higher pain scores decreased.

In the tabulated data, a boundary zone emerged (Table 6). No subject experienced pain of intensity 6. No subject experienced pain of intensity 5 below 40 psi a.o. No subject experienced pain of intensity 3 or 4 below 30 psi a.o.; and no subject experienced pain at pressures less than 20 psi a.o.

A secondary boundary zone was also evident (Table 6). No more than 10% of the subjects experienced pain of intensity 5 despite pressurization

Table 3 Correlation between disc morphology and pain response in asymptomatic subjects undergoing discography

	Pain	No Pain	P Value
MRI grade			0.26
I	0	0	
II	6	7	
III	6	10	
IV	6	6	
V	1	1	
Anular disruption			0.71
0	4	6	
1	0	0	
2	4	3	
3	14	12	

to 100 psi a.o. No more than 10% of the subjects experienced pain of intensity 3, or 4 at pressures below 40 psi a.o. Only 10% of subjects experienced any pain below a pressure of injection of 30 psi a.o.

Discussion

Normal volunteers for studies of invasive procedures are difficult to recruit. Discography is demanding procedure for it requires the subject to lie still and cooperate while the investigator inserts needles deeply into multiple sites. Lay individuals could be excused for considering this sort of experience threatening. For that reason, we sought to recruit volunteers with some insight into the procedure or who knew the investigators and trusted them.

The resulting sample was small, but comparable in size to those used in previous studies involving normal volunteers [27,28]. The present sample

included individuals who denied any history of low back pain and individuals who reported less than three episodes of back pain in the previous year. The responses to discography of these two groups were not different and so, their responses could be pooled. Nor were the responses of the physicians in any way different from those of the lay volunteers. The data did not reveal any bias among the physicians to under-report either the incidence or intensity of pain.

The first result of the present study was that lumbar discs can be made to hurt in asymptomatic volunteers. However, it is not true that all discs will be painful if stimulated strongly enough. Many discs tolerate high pressures of injection without becoming painful. Nevertheless, some 50% of discs become painful; but the response is variable, and depends on the segmental level stimulated, the nature of disc, and the intensity of stimulation.

When painful, asymptomatic discs are only mildly so. Subjects rate the pain as only 2 or 3 on a 10-point scale, on average. More intense pain is uncommon, and reached 5 in only three instances in the present study. Intriguingly, there was a tendency for L3-4 discs to be not painful; L4-5 discs to be mildly painful; and L5-S1 discs to be more painful by one grade. Thus, segmental level seems to be a determinant of whether or not a disc will be painful.

Magnetic resonance imaging appearance is not a determinant of whether or not a disc will be painful, but its internal morphology, as seen on CT discography, is. All but three painful discs in the present study exhibited grade 3 anular tears. Although this condition does not guarantee that a disc will be painful, it does seem to be a requisite.

Table 4 Distribution by segmental level of pressures tolerated by asymptomatic subjects undergoing discography

Segment	Pressure (psi a.o.)										
	0	10	20	30	40	50	60	70	80	90	100
No LBP											
L1-2							●				
L2-3						○		○			
L3-4					●		○ ○ ●				○ ○ ○
L4-5			●	●		●	○	○ ●		●	
L5-S1			●	●		●		○ ●			○
Occasional LBP											
L1-2											○ ○
L2-3				○			○				○ ○
L3-4							○		○ ○	○	○ ○
L4-5				● ●	●			●		○	○
L5-S1			●	●							○

● = pain experienced; ○ = no pain; LBP = low back pain; psi a.o. = pounds per square inch above opening.

Table 5 Distribution by segmental level of pain scores reported by asymptomatic subjects undergoing discography

Segment	Pain Score										
	0	1	2	3	4	5	6	7	8	9	10
No LBP											
L1-2			1								
L2-3	2										
L3-4	5	1		1							
L4-5	2	3		2							
L5-S1	2	2			1	1					
Occasional LBP											
L1-2	2										
L2-3	2										
L3-4	6										
L4-5	2	2			1	1					
L5-S1	1				2	1					

LBP = low back pain.

Conversely, a disc is less likely to be painful if it has lesser, or no, internal disruption. In this regard, the present study was compromised by a relatively small sample size, in which very few discs were completely normal morphologically or had only grade 1 or grade 2 annular tears (Table 3). This limited the ability of the present study to show an association between absence of pain and absence of grade 3 fissures. Larger studies, which included

more patients with normal discs, have shown that painful discs are concentrated among those with grade 3 fissures while discs without fissures are almost all painless [33].

The second, and important, result of the present study is that asymptomatic discs differ in threshold for pain sensitivity. As a rule, asymptomatic discs tolerate substantial or high pressures of injection before becoming painful; and in that event are most often only mildly painful.

The combination of high pressure of injection and low intensity of response provides for operational criteria to be derived by which to minimize the false-positive rate of lumbar discography. Those criteria are composite. They require a pain score and a pressure of injection, but the tolerable pain score differs with pressure of injection.

Figure 1 shows a receiver-operator curve based on the present data. It demonstrates that false-positive responses occur only above certain pressures and pain scores. Reciprocally, certain pain scores below certain pressures produce no false-positive responses. Pain scores greater than 5, at any pressure of injection up to 100 psi a.o., do not occur in asymptomatic individuals and so, would be true-positive if they occurred in patients. Similarly, pain scores greater than 4, at pressures up

Table 6 The probability of experiencing pain at the intensity indicated and the pressure indicated, during discography in with no low back pain (No LBP) or occasional low back pain (Occ LBP)

Pressure (psi a.o.)	Group	Pain Score						
		0	1	2	3	4	5	6
100	No LBP	0.25	0.75	0.44	0.13	0.00	0.00	0.00
	Occ LBP	0.46	0.54	0.38	0.23	0.15	0.08	0.00
90	No LBP	0.25	0.75	0.44	0.13	0.00	0.00	0.00
	Occ LBP	0.46	0.54	0.38	0.22	0.15	0.08	0.00
80	No LBP	0.31	0.69	0.38	0.06	0.00	0.00	0.00
	Occ LBP	0.53	0.47	0.33	0.20	0.13	0.07	0.00
70	No LBP	0.42	0.58	0.32	0.05	0.00	0.00	0.00
	Occ LBP	0.59	0.41	0.29	0.18	0.12	0.06	0.00
60	No LBP	0.64	0.36	0.27	0.05	0.00	0.00	0.00
	Occ LBP	0.64	0.35	0.29	0.18	0.12	0.06	0.00
50	No LBP	0.70	0.30	0.22	0.04	0.00	0.00	0.00
	Occ LBP	0.68	0.32	0.26	0.18	0.11	0.05	0.00
40	No LBP	0.78	0.22	0.17	0.04	0.00	0.00	0.00
	Occ LBP	0.68	0.25	0.26	0.18	0.11	0.05	0.00
30	No LBP	0.83	0.17	0.13	0.00	0.00	0.00	0.00
	Occ LBP	0.75	0.25	0.20	0.10	0.05	0.00	0.00
20	No LBP	1.00	0.09	0.09	0.00	0.00	0.00	0.00
	Occ LBP	0.90	0.10	0.10	0.00	0.00	0.00	0.00
10	No LBP	1.00	0.00	0.00	0.00	0.00	0.00	0.00
	Occ LBP	1.00	0.00	0.00	0.00	0.00	0.00	0.00

The solid line indicates the intensities and pressures below which the probability of experiencing pain is zero. The dashed line indicates the intensities and pressures below which the probability of experiencing pain is 10% or less. psi a.o. = pounds per square inch above opening.

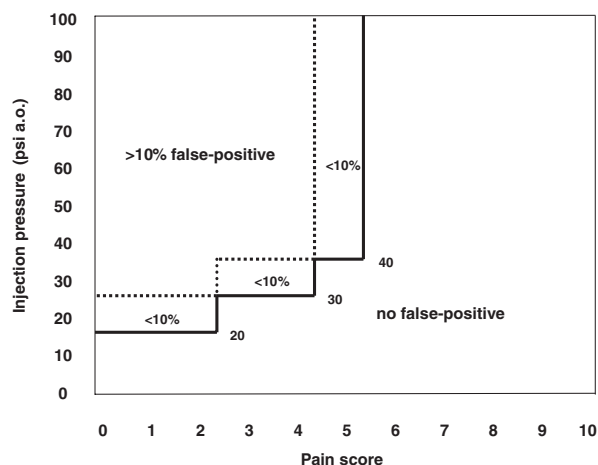


Figure 1 A receiver–operator curve showing the combined pressures and pain scores, below which no false-positive or less than 10% false-positive response might be expected during discography in symptomatic patients, and above which false-positive response have a likelihood greater than 10%. psi a.o. = pounds per square inch above opening.

to 40 psi a.o., would be true-positive. Pain scores greater than 2, at pressures up to 30 psi a.o., would be true-positive; and any pain, at pressure up to, but not exceeding 10 psi a.o., would be true-positive.

If operators are satisfied to carry a 10% risk of false-positive responses, a different boundary applies, as depicted in Figure 1. Any pain score, at pressure up to 20 psi a.o., has a no more than 10% chance of being false-positive. Pain scores greater than 4, at pressures up to 100 psi a.o., have a less than 10% chance of being false-positive.

These operational criteria are compatible with those that emerge from other studies. Walsh et al. [27] found no disc to be painful in any of their subjects, but they did not reveal the pressure to which they tested their discs. Carragee et al. [28] reported that 10% of the discs in their asymptomatic patients were painful. That amounted to one disc that was painful at 25 psi a.o. No other asymptomatic volunteer in that study experienced pain of intensity greater than 4 at pressures up to 50 psi a.o.

Combining the present results with those of Carragee et al. [28] indicates that if the operational criteria for discography are set as pressure not greater than 50 psi a.o., and intensity of evoked pain to be greater than 4, the false-positive rate will be less than 10%. This false-positive rate should be acceptable, given that discography and its consequences are not life-threatening. How-

ever, a false-positive rate of zero can be secured either if the required pain score is held at 4 and the threshold pressure of injection is lowered to 30 psi a.o.; or if the required pressure is held at 50 psi a.o and the pain score required is raised to 6.

What the present study shows is that lumbar discography cannot be dismissed with sweeping statements. It does not have alarmingly high false-positive rates. The study suggests that possible false-positive responses can be reduced, and even eliminated, by using composite operational criteria that take into account simultaneously both the intensity of response and the strength of stimulation. No single figure serves to define what should constitute a positive response in symptomatic patients, but the receiver–operator curve (Figure 1) constitutes a reference.

The present results, and those of Carragee et al. [28], underscore the importance of recording both pain response and pressure of injection at the time of discography. Both variables affect the interpretation of the response. Discography without pain scores and without manometry cannot be considered to be valid. But if both are used, discography can be rendered valid by adopting the operational criteria defined by the present study.

Applying these criteria to patients inherits a number of difficulties but also some advantages. Patients may be different to asymptomatic volunteers, in that they may be apprehensive, anxious, or suffer from hyperalgesia. This could affect the threshold at which they feel pain, or the intensity of their pain-rating. The pressure and pain thresholds identified in this study therefore can only be indicative of what should be normal. Operators should interpret with care responses in patients at low pressures of stimulation, lest they be false-positive. For this reason, testing adjacent discs becomes critical. If a patient clearly identifies one disc as painful at low pressure of injection, but control discs are not painful, their response is not compatible with generalized anxiety or hyperalgesia. Furthermore, in patients the additional criterion of concordant pain applies. Disc stimulation should not simply be painful; it must reproduce the patient's accustomed pain. By definition, this criterion cannot be tested in asymptomatic volunteers. It applies in addition to the manometric criteria defined in the present study.

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