

Supplementary Materials

Patient perspectives on AI: a pilot study comparing large language model and physician-generated responses to routine cervical spine surgery questions

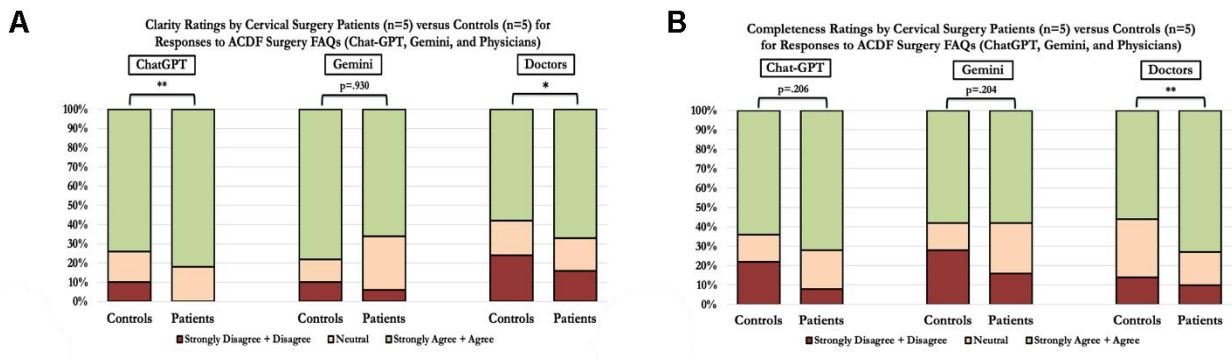
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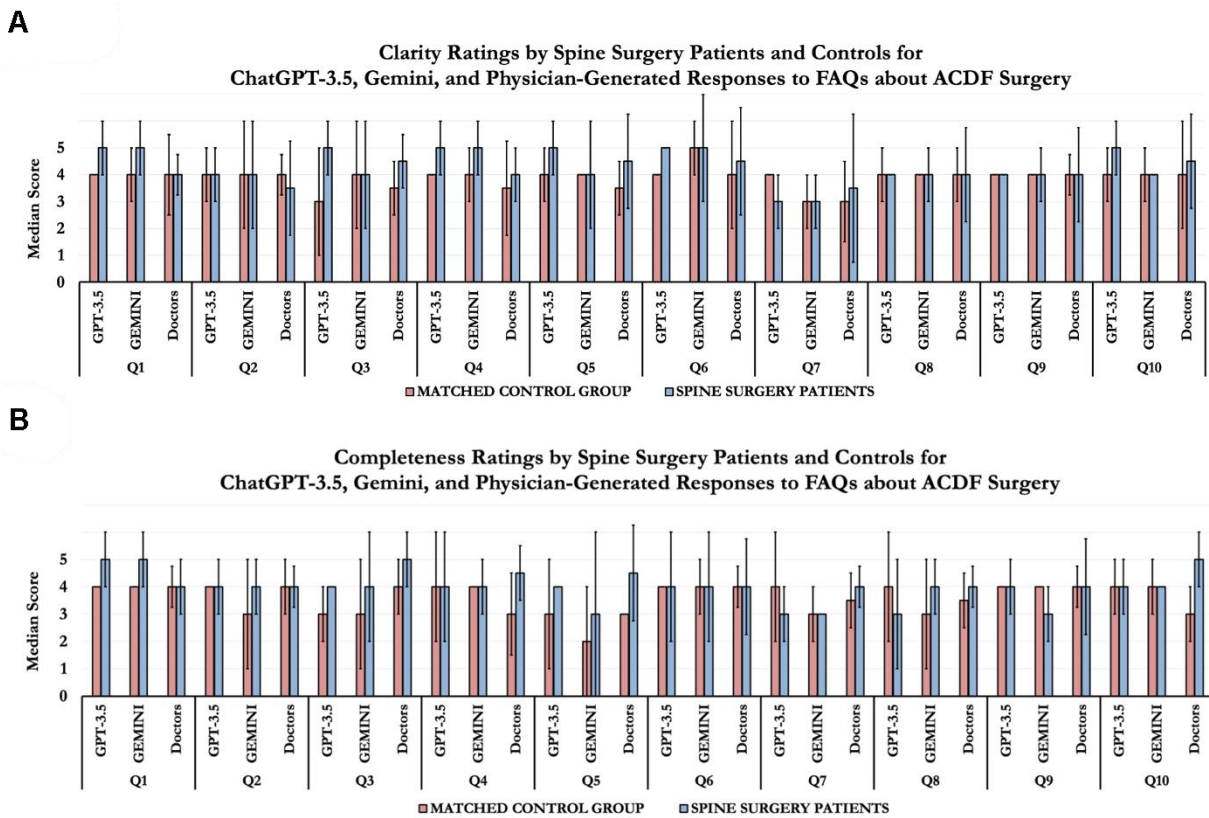
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Supplementary Figure 1. (A) Clarity and (B) completeness ratings, expressed in percentages, from cervical spine surgery patients ($n = 5$) and age-matched controls ($n = 5$) comparing answers generated by ChatGPT-3.5, Gemini, and Physicians.



Supplementary Figure 2. (A) Median clarity and (B) completeness ratings for individual questions from cervical spine surgery patients ($n = 5$) versus age-matched controls ($n = 5$) comparing answers from ChatGPT-3.5, Gemini, and Physicians. Error bars represent IQR from the 25th through the 75th percentile.

Supplementary Table 1. Responses to frequently asked questions about ACDF surgery by ChatGPT-3.5, Gemini, and doctors

	Responder	Response
Question 1	ChatGPT-3.5	Anterior Cervical Discectomy and Fusion (ACDF) surgery is a procedure used to treat cervical spine issues, often caused by herniated discs or degenerative conditions. During ACDF, an incision is made in the front of the neck, allowing access to the cervical spine. The damaged disc is removed (discectomy), and then a graft material, typically bone, is inserted into the space left by the removed disc. This graft encourages the vertebrae to fuse together (fusion), stabilizing the spine.
	Gemini	ACDF surgery is a common procedure to treat neck pain caused by a herniated or degenerated disc. It involves removing the damaged disc and fusing the vertebrae above and below to stabilize the spine. Procedure Overview: 1. Incision: An incision is made in the front of the neck, allowing access to the affected disc. 2. Disc Removal: The surgeon carefully removes the herniated or degenerative disc material. 3. Bone Graft Placement: A bone graft, from the patient or a donor, is inserted into the disc space to promote fusion between the vertebrae. 4. Stabilization: Plates, screws, or other devices may be used to stabilize the fused segment.
	Doctor 1	ACDF surgery is a spinal procedure done under general anesthesia. The goal of the surgery is to relieve pressure on the spinal cord or the nerve roots in the cervical spine. In this procedure, one or more of the discs in the cervical spine are removed and the adjacent segments are fused. This is normally done by placing an intervertebral cage or bone graft and the placement of a plate or a bracket to provide fixation of those vertebral segments.
	Doctor 2	In your neck, as in the rest of your spine, you have discs and when the discs bulge, herniate, or compress on the nerves, we sometimes need to take them out. Because the spinal cord is behind it, you can't go in from the back like you do in the lumbar spine, so you must go in from the front because we don't want to move the spinal cord. So,

		<p>the front sounds kind of scary because it's all sorts of important structures, but we basically go in between those structures to get to the disc and then we take the disc out so it's no longer compressing the nerves of the spinal cord. But because if we just leave the gap there, we need to put something in there. And so that's why we need to do a fusion, so it doesn't collapse down. So that's kind of the basics of how we do the surgery.</p>
Question 2	ChatGPT-3.5	<p>Recovery and fusion times can vary, but generally, you may need 6-8 weeks before returning to work and normal activities. Complete fusion typically takes several months. Your specific timeline depends on your overall health and the number of cervical discs involved.</p>
	Gemini	<p>Recovery typically takes several weeks to months. Fusion occurs gradually, with complete fusion taking up to 18 months. Most patients can return to work and daily activities within 4-6 weeks.</p>
	Doctor 1	<p>We can start with recovery. Recovery depends somewhat on the number of segments that have undergone surgery. Most of these surgeries are either a one motion segment, two motion segment, or three motion segment or one-level, two-level, three-level fusion. In some cases, you may be able to go home the same day. But most patients in my practice would stay overnight in the hospital for observation. Particularly if the procedure is a three-level surgery. Then they would be discharged from the hospital once they meet certain criteria and those criteria would be that the bowel and bladder functions have returned to normal, they're not having nausea., they're not having severe pain that requires IV medication. And they're otherwise medically stable with no concerning medical signs and then normally those patients would be able to go home; as I said, it's usually the day after surgery or 2 days after surgery in some cases. The next phase of their recovery is a 6-week period where they would in my practice wear a neck brace, which is a hard, cervical collar. This should be worn at all times for 6 weeks. In this time, you shouldn't be doing much bending of your neck, twisting of</p>

		<p>your neck, and you should generally lift no more than 15 pounds of weight. After 6 weeks, you would move on to the next stage of your recovery. All being well, we can discontinue the use of your neck brace and then you should start physical therapy. This is an important part of your overall treatment, the rehab provided by physical therapy and this should go on for a further two months or so. And by the end of that period, you should be largely recovered from the surgery and experiencing the benefits. However, sometimes recovery could take up to a year. You would return to work depending on your profession, you know, based on those restrictions. So if you were working in an office job, potentially you could go back to work in 4 weeks; if you were needing to do a lot of bending of your neck at work, it may be 2 to 3 months after your rehab is completed. And similarly, with your daily activities, your daily activities would gradually return to normal daily activities after 6 weeks after surgery.</p>
	<p>Doctor 2</p>	<p>I tell patients that the full recovery is probably about 3 months. But you're up and out of a bed, you know, basically the same day and you're moving around. Depending on how many levels we do, you may or may not need a collar. And the symptoms that you had before the surgery may get better in a few days or take longer depending on how severe the compression was and how long you've had it. So we check on you periodically and see how you're healing and wean from the collar when the healing is good enough. And then you can start returning to activities as per the healing is indicated. And so you'll be doing most of your daily activities certainly by 3 months but usually by 6 weeks, but other more rigorous sports may take longer for you to get your strength and fitness back.</p>
<p>Question 3</p>	<p>ChatGPT-3.5</p>	<p>Fusion materials often include bone grafts from your hip (autograft), cadaver bone (allograft), or synthetic bone substitutes. Complications may include graft rejection, infection, or hardware issues like screws loosening.</p>

	Gemini	Common fusion materials include autograft (patient's own bone), allograft (donor bone), or synthetic bone substitutes. Complications include infection, non-union (failure to fuse), and hardware problems.
	Doctor 1	The material used for fusion is generally titanium and a bone graft. So, the fusion occurs biologically when one bone is incorporated into the adjacent bone and to encourage this, we use titanium cages that are packed with a bone graft. In my practice, these bone grafts are packed with a bone graft. In my practice, these bone grafts are usually bone from a donor. Some of the medical complications include heart problems, lung problems, blood clots, and DVTs. Infections can occur as well in the skin or the bone. And the other complications can include swallowing difficulty, which rarely can last for several months or even be permanent. Similarly, hoarse voice is common in the early period, but likely resolves within 6 weeks. And finally, neurological injury is possible in this procedure as well.
	Doctor 2	We have to put something in the space where we take out the disc, as I've mentioned earlier. I usually prefer to put in bone, but other doctors put in a spacer that might be made out of either a surgical plaster or surgical steel mesh. But it's basically to hold the space open and allow the bone to heal around it. And then, we usually put a plate on to hold everything in place so it heals properly. The main complications are associated with either getting there because, as I said earlier, there are important structures there, most of which can be avoided and most of which don't happen, but there's always the risk. Then, because we're taking the disc out right next to where the spinal cord and nerves are, there is certainly the risk of nerve injury, such as weakness or paralysis. Again, those are very rare. With respect to the materials, most of the materials have been tested quite extensively, so don't cause reactions or problems per se, but one of the risks of the procedures if the fusion doesn't heal is that the materials can eventually break because if the fusion doesn't heal, we

		<p>can have what we call micromotion, a little bit of motion that can eventually cause the plate to break for example. This is one of the reasons we take X-rays is to follow this and make sure things are healing and healing in the right direction and there's minimal risk of that.</p>
Question 4	ChatGPT-3.5	<p>ACDF surgery is recommended for conditions causing spinal cord or nerve compression, leading to pain, weakness, or numbness. Benefits can include pain relief and improved nerve function. Risks include infection, nerve injury, and hoarseness.</p>
	Gemini	<p>ACDF is recommended for neck pain, arm pain, numbness, or weakness caused by a herniated or degenerated disc. Risks include infection, nerve damage, and blood clots. Benefits include pain relief, improved function, and stability.</p>
	Doctor 1	<p>There are 2 main indications for a ACDF surgery, one would be a cervical radiculopathy where a nerve root is compressed and the symptoms from this did not improve despite conservative treatment. The second general indication would be development of cervical myelopathy where the spinal cord is compressed and is in the process of potentially irreversible damage, and then those patients should have surgery also. I think we talked about the risks already. The benefits are that in the setting of radiculopathy, there is a high chance, although no guarantee, of the radiculopathy symptoms improving after the surgery and the subsequent physical therapy. In terms of myelopathy, the likely benefit is that the myelopathy will no longer worsen and there is a chance that the symptoms from myelopathy will gradually improve as well.</p>
	Doctor 2	<p>We usually do this kind of surgery because there's compression by the disc or there's bone spurs next to the disc on the spinal cord or the nerves that come out of the spinal cord within the neck, which can give you pain, numbness, or weakness in your arms. Or if the spinal cord is compressed, it can give you weakness in your legs or problems with balance or even bladder problems. So any of those reasons could be a reason for an ACDF. And potential benefits</p>

		obviously are improving those symptoms and preventing them from getting worse or potentially reversing those. And so those are the reasons that people think about having surgery for usually those symptoms that I've mentioned. And the risks are largely, you know, the risks, as I've mentioned earlier, that there are lots of important structures around it from the structures in the front of the neck that we have to part or separate to get to the disc or that the nerves could potentially be at risk for damage. Because you're working in front of it, you're not pushing the spinal cord or nerves to the sides. It's less risky than from the back, where we'd have to push the nerves to the side, and so that's why it's usually done coming from the front.
Question 5	ChatGPT-3.5	Long-term outcomes are generally positive, with success rates ranging from 80-90%. Potential long-term effects may include adjacent disc degeneration. Risks are minimal, but long-term success depends on proper postoperative care.
	Gemini	ACDF is generally successful in relieving symptoms and improving function. Long-term success rates range from 70-90%. Potential long-term effects include stiffness and adjacent disc degeneration.
	Doctor 1	In the setting of radiculopathy, a significant improvement in patient's symptoms is approximately 70%. That means 7 out of 10 patients would improve and would report about 6 months after surgery that their symptoms are significantly improved. And in the setting of myelopathy, approximately 60% of patients would improve and report that one year after surgery, some of their symptoms had improved. And the vast majority would report that their symptoms are no longer worsening, so those would be considered successful outcomes.
	Doctor 2	When it comes to relieving a patient's arm symptoms or spinal cord compression, ACDF surgery is usually quite successful at doing that, but the reversal of the symptoms may be variable depending on how severe the compression is and how long it's been going on. It can take anywhere from 6 months to 2 years to know how much that can be reversed. The outcome and success rate depend on those

		<p>things, but usually, patients have stopping of the progression or significant improvement of symptoms, especially if they're related to arm symptoms. Long-term effects are largely related to the fact the part of the spine that's fused doesn't move anymore, and so for one or two levels near the fusion, there is added stress put at these levels. Most patients don't notice this because there's so much mobility in the neck. Now, if you didn't have a fusion, they could also wear out, so it might accelerate a little bit, but it's not unique to the fact just having the spine fusion.</p>
Question 6	ChatGPT-3.5	<p>Post-surgery precautions include wearing a neck brace, avoiding heavy lifting, and limiting neck movement. Follow your surgeon's guidance to ensure proper healing.</p>
	Gemini	<p>Wear a neck brace as instructed and avoid strenuous activities, lifting, and bending.</p>
	Doctor 1	<p>As discussed, you would wear a neck brace for 6 weeks after surgery and avoid bending, twisting, lifting at that time.</p>
	Doctor 2	<p>The neck brace is oftentimes used just to protect you from moving your neck excessively while the bone heals. The screw holds things in place, but you can imagine if you had a plate on something and you just kept moving the two moving parts, eventually the plate and the screws would loosen, so you don't want to fatigue the plate that we put in during the time of surgery, and so that's what the neck braces remind you not to do. And again, depending on how many levels and how your fusion is going. I or your surgeon might have slightly different lengths of time you'd wear the neck brace. And the activities to avoid include excessive neck motion, we certainly wouldn't want you to be doing things that would land on your head. For example, you can go back to swimming but no diving for 6 or 8 weeks. You could ride a bike, but you probably wouldn't want to ride a road bike where you're really low and you have to kind of extend your neck a lot. But that also depends on how many levels need to be fused. So eventually, hopefully, aside from the fact that you lose a little bit of flexibility, it shouldn't affect your long-term</p>

		activity very much.
Question 7	ChatGPT-3.5	Post-surgery, expect a small incision scar and some discomfort. Pain management options will be provided to keep you comfortable.
	Gemini	Expect a small incision, minimal scarring, pain management, and temporary discomfort.
	Doctor 1	As this is a major surgery, you can expect significant pain from surgery. Normally, patients are able to have their pain controlled on oral narcotics by day one after surgery. And oral narcotics are typically needed for at least one week after surgery. But then there is a great deal of variation, and many patients would just need one week or even less of narcotics. Some patients may need up to 4 to 6 weeks of oral narcotics to control their pain. And after being off the narcotics, we would transition to Tylenol and then, of course, transition the Tylenol to no pain medication over time. In terms, the other thing to say is non-steroidal anti-inflammatories such as ibuprofen are contraindicated in the postoperative period. And then the other thing is that in terms of your incisions and scars, this may depend on how many levels are fused, but for one- or two-level fusions, you can expect a horizontal incision and subsequent scar and more of a longitudinal or diagonal incision for a three-level ACDF. In terms of scarring, this is variable according to the patient, but in many instances, a horizontal scar heals very well and is very inconspicuous, matching the natural crease in the neck.
	Doctor 2	We make an incision in the front of your neck and we make it where most people have some skin creases, so we try to keep it near a crease so they actually heal pretty well. I have a few people who are Keloid formers, but most patients don't seem to form a lot of keloids in these areas. So the insertions heal pretty well and same thing with the scar. Depending on whether you need a lot of levels done, sometimes pain management can be a little bit of a problem. But it isn't usually a long-term problem, but rather, it is usually a short-term issue. Potential discomfort is possible but not common to have some pain that you didn't have before surgery. What's more

		common is if we don't get rid of all your arm pain, for example, or all your neck pain. So it's usually the case where we weren't able to get rid of all of your symptoms, but this is partly related to how long you might have had the nerve compression. In general, most patients don't complain about a new discomfort, but it can happen
Question 8	ChatGPT-3.5	Hospital stays are typically 1-2 days. Physical therapy may be needed, especially if multiple discs were treated.
	Gemini	Most patients stay 1-2 days in the hospital. Physical therapy is often recommended to regain strength and flexibility.
	Doctor 1	Most patients go home the day after surgery. Some patients even managed to go home the same day, and then in longer, bigger fusion, such as three levels, they may stay two nights in hospital. And physical therapy as discussed would in my practice begin after six weeks of wearing a neck brace have been completed.
	Doctor 2	If it's just a single level that we're doing, then overnight would be probably the longest. Some patients can have surgery done in the morning and would be able to leave that night. We do like to keep you here for a few hours just to make sure that there's not too much swelling in the area that we do the surgery in and/or bleeding in that area that would cause you problems with breathing. But that's usually an acute problem. And physical therapy, I have a few patients who decline physical therapy, but most patients seem to benefit from getting some therapy to improve their neck strength and, you know, learn to move again, but it's not too extensive in most cases.
Question 9	ChatGPT-3.5	ACDF surgery duration varies but often takes 1-2 hours per disc.
	Gemini	ACDF typically takes 1-2 hours.
	Doctor 1	This is dependent on how many levels are fused. One level typically takes about 90 min, two levels take about two to two and a half hours and three levels take about 2 and a half hours.
	Doctor 2	I tell patients that it's about an hour to an hour and a half per level. Just between the setup time and getting them positioned well and taking X-rays, things like that or whatever, that's probably a good

		<p>guideline on how long we should take. Obviously, there're some people who have other conditions that might make it more complicated or prior surgery that might make it more scarred, but that's probably a good average.</p>
<p>Question 10</p>	<p>ChatGPT-3.5</p>	<p>Alternative treatments include conservative options like physical therapy or medications. Repeat ACDF may be considered if new disc issues arise. Your surgeon will evaluate the necessity on a case-by-case basis.</p>
	<p>Gemini</p>	<p>Non-surgical options include physical therapy, pain medication, and injections. ACDF may be repeated for other disc issues if conservative treatments fail.</p>
	<p>Doctor 1</p>	<p>The surgery may be repeated in the same patient if a disc issue arises down the line in that patient. The most common setting for this would be a condition called adjacent level disease, where the adjacent disc to the fusion into the fuse disc degenerates, and the patient experiences radiculopathy or myelopathy. The rates are approximately 4 out of 10 patients within ten years of ACDF surgery. In terms of alternatives to ACDF, this will depend on the condition for which the ACDF was performed. If the ACDF was performed for the condition of a unilateral, one-sided radiculopathy, then an alternative procedure could be a cervical foraminotomy or potentially an artificial disc replacement. If the procedure is performed for a cervical myelopathy, then alternatives could be an artificial disc replacement versus a posterior approach such as a cervical laminectomy with or without fusion or a laminoplasty.</p>
	<p>Doctor 2</p>	<p>Sure, so there are some patients who might be good candidates for a disc replacement. And that depends on the type of disc herniation you have, how strong your bone is, how many levels would be involved, and the kind of bone spurs you might or might not have next to the disc herniation. Depending on the patient that I'm talking to, I might say that would be an option for you or that isn't really an option for you. And then for some patients who need multiple-level ACDFs, a posterior operation, a decompression and fusion or a</p>

		<p>laminoplasty might be indicated. These alternatives might not be applicable for every situation, but I would go through why they might or might not be appropriate. The biggest thing I think would be an alternative to ACDF would be whether or not a patient is a candidate for disc replacement.</p>
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Supplementary Table 2. Clarity and completeness rating differences between three responding platforms (ChatGPT-3.5, Gemini, and doctors) and two groups of raters (cervical spine surgery patients and age-matched control group)

Group	Comparison	Question	<i>P</i>-values
Cervical Spine Surgery Patients		Clarity	Q1. <i>P</i> = 0.752
			Q2. <i>P</i> = 0.222
			Q3. <i>P</i> = 0.880
	Doctors and Gemini	Clarity	Q4. <i>P</i> = 0.596
			Q5. <i>P</i> = 0.880
			Q6. <i>P</i> = 1.00
	Doctors and Gemini	Completeness	Q7. <i>P</i> = 0.783
			Q8. <i>P</i> = 0.578
			Q9. <i>P</i> = 0.583
		Completeness	Q10. <i>P</i> = 0.954
			Q1. <i>P</i> = 0.586
			Q2. <i>P</i> = 0.831
		Completeness	Q3. <i>P</i> = 0.576
			Q4. <i>P</i> = 0.511
			Q5. <i>P</i> = 0.611
	Doctors and Gemini	Completeness	Q6. <i>P</i> = 1.00
			Q7. <i>P</i> = 0.783
			Q8. <i>P</i> = 0.578
		Completeness	Q9. <i>P</i> = 0.583
			Q10. <i>P</i> = 0.854
			Q1. <i>P</i> = 0.139
		Clarity	Q2. <i>P</i> = 0.108
			Q3. <i>P</i> = 0.635
			Q4. <i>P</i> = 0.596
	Doctors and Gemini	Clarity	Q5. <i>P</i> = 0.364
			Q6. <i>P</i> = 0.362
			Q7. <i>P</i> = 1.00
	Clarity	Q8. <i>P</i> = 0.876	
		Q9. <i>P</i> = 0.842	

	Doctors and ChatGPT-3.5		Q10. $P = 0.384$
		Completeness	Q1. $P = 0.053$ Q2. $P = 0.083$ Q3. $P = 0.481$ Q4. $P = 0.347$ Q5. $P = 0.675$ Q6. $P = 1.00$ Q7. $P = 0.684$ Q8. $P = 0.084$ Q9. $P = 0.713$ Q10. $P = 0.663$
	Gemini and ChatGPT-3.5	Clarity	Q1. $P = 0.481$ Q2. $P = 0.740$ Q3. $P = 0.524$ Q4. $P = 1.00$ Q5. $P = 0.273$ Q6. $P = 0.446$ Q7. $P = 0.681$ Q8. $P = 0.446$ Q9. $P = 0.694$ Q10. $P = 0.242$
		Completeness	Q1. $P = 0.481$ Q2. $P = 0.217$ Q3. $P = 1.00$ Q4. $P = 0.740$ Q5. $P = 0.291$ Q6. $P = 1.00$ Q7. $P = 0.273$ Q8. $P = 0.524$ Q9. $P = 0.095$

			Q10. $P = 0.740$
Age-Matched Control Group	Doctors and Gemini	Clarity	Q1. $P = 0.195$ Q2. $P = 0.262$ Q3. $P = 0.803$ Q4. $P = 0.020$ Q5. $P = 0.094$ Q6. $P = 0.115$ Q7. $P = 0.724$ Q8. $P = 0.740$ Q9. $P = 0.471$ Q10. $P = 0.141$
		Completeness	Q1. $P = 0.455$ Q2. $P = 0.025$ Q3. $P = 0.242$ Q4. $P = 0.359$ Q5. $P = 0.471$ Q6. $P = 0.305$ Q7. $P = 0.040$ Q8. $P = 0.347$ Q9. $P = 0.471$ Q10. $P = 0.724$
	Doctors and ChatGPT-3.5	Clarity	Q1. $P = 0.305$ Q2. $P = 0.724$ Q3. $P = 0.402$ Q4. $P = 0.172$ Q5. $P = 0.681$ Q6. $P = 0.273$ Q7. $P = 0.273$ Q8. $P = 0.545$ Q9. $P = 0.347$ Q10. $P = 0.141$
			Q1. $P = 0.667$ Q2. $P = 0.126$

		Completeness	Q3. $P = 0.115$ Q4. $P = 1.00$ Q5. $P = 0.694$ Q6. $P = 0.471$ Q7. $P = 0.207$ Q8. $P = 0.545$ Q9. $P = 0.608$ Q10. $P = 0.290$
	Gemini and ChatGPT-3.5	Clarity	Q1. $P = 0.545$ Q2. $P = 0.481$ Q3. $P = 0.308$ Q4. $P = 0.347$ Q5. $P = 0.111$ Q6. $P = 0.455$ Q7. $P = 0.141$ Q8. $P = 0.273$ Q9. $P = 0.694$ Q10. $P = 1.00$
		Completeness	Q1. $P = 0.608$ Q2. $P = 0.347$ Q3. $P = 0.803$ Q4. $P = 0.516$ Q5. $P = 0.771$ Q6. $P = 0.545$ Q7. $P = 0.535$ Q8. $P = 0.771$ Q9. $P = 0.740$ Q10. $P = 0.486$

Statistical significance was set at $P = 0.005$ following Bonferroni correction.