

Virtually painless – how VR is making surgery simpler

January 31 2017, by Jo Marchant

Surgeons and their patients are finding that virtual reality can relieve the pain and stress of operations – and it's safer and cheaper than sedatives. Jo Marchant travels to a Mexican mountaintop village to visit a clinic with a difference.

Ana Maria has never been to Machu Picchu. The 61-year-old always wanted to visit the mountain ruins but she suffers from hypertension, and doctors warned that the extreme altitude could cause her blood pressure to rise dangerously high. Today, dressed in a white gown and hairnet, she will explore its ancient walls and pyramids for the first time.

She's in a private medical clinic in Mexico City, and laughs nervously as she's wheeled into a windowless operating room. The surgeon takes a Sharpie and draws a large circle on her left thigh, paints on several layers of iodine, then injects a local anaesthetic into the skin. Inside the circle is a fatty lump, a lipoma around 6 cm across, which he is about to remove.

Ana will be awake for the operation, and she's feeling scared. As the surgeon readies his scalpel, her blood pressure is 183/93, even higher than usual. Patients undergoing procedures like this often have to be sedated to cope with the pain and anxiety of being under the knife, but not today. Instead, José Luis Mosso Vazquez, who is supervising the operation, fits a sleek, black headset over Anna's eyes and adjusts the Velcro straps.

The surgeon makes his first cut and the blood spills in a crimson stream down Ana's leg. She's surrounded by medical equipment – stools, trolleys, swabs, syringes, with super-bright surgical lamps suspended above the bed and her vital signs displayed on monitors just behind. But Ana is oblivious. She's immersed in a three-dimensional re-creation of Machu Picchu. She begins her journey with a breathtaking aerial view of the ancient city clinging to the mountainside, before swooping down to explore the details of stepped terraces, moss-covered walls and tiny stone huts.

Mosso watches her carefully. A 54-year-old surgeon at Panamerican University in Mexico City, he's on a mission to bring virtual reality into the operating room, using the high-tech distraction technique to carry out surgeries that would normally require powerful painkillers and sedatives, with nothing more than local anaesthetic. He's trying to prove that reducing drug doses in this way not only slashes costs for Mexico's cash-strapped hospitals, but cuts complications and recovery times for patients, too.

But today, he's not sure if his headset is going to be enough. He hopes the virtual reality will help Ana to avoid unnecessary medication, but if she becomes anxious during the surgery, her already-high vital signs might spike. He has prepared an intravenous line, ready to administer emergency medication if required.

The surgeon pulls a large, pearly glob of tissue from Ana's thigh, his fingers easing under her skin as he carefully snips it free. Then he mops the blood and stitches the wound. The procedure has taken just 20 minutes, and there are smiles all round as Ana thanks the team. Because of the virtual reality, she says, she barely noticed the scalpel slicing her flesh: "I was transported. Normally I'm very stressed, but now I feel so, so relaxed."

The monitors back up her story. Throughout the surgery, her blood pressure actually fell.

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In 2004, Mosso bought a Spider-Man game for his eldest son, and his life and career path changed. The game involved images projected onto a head-mounted display – an early form of virtual reality (VR). Mosso was struck by how immersed his son became in the game. "His Mom called him to go to dinner and he didn't hear her, nothing. I thought, what if I use this on a patient?"

Mosso began using the game during upper gastrointestinal endoscopies, in which a flexible tube with a camera on the end is fed through a patient's throat into their stomach. The experience can be unpleasant and distressing. Patients often require sedation but Mosso encouraged them to play the Spider-Man game instead, to distract themselves.

He asked the patients to score their pain and anxiety during the procedure and in 2006 presented his results at the Medicine Meets Virtual Reality conference in California. The idea of using VR to reduce the distress of medical procedures was pioneered at the University of Seattle, Washington, where cognitive psychologist Hunter Hoffman and colleagues have developed a VR game called SnowWorld, to help patients endure wound care for severe burns. The researchers hoped that the illusion of being physically immersed in a three-dimensional computer-generated scene would move patients' attention away from their real-world pain. It worked: Hoffman's team has since shown in trials that SnowWorld reduces patients' pain during wound-care sessions by up to 50 per cent, as well as reducing pain-related brain activity.

But there has been relatively little work in other medical contexts. At the 2006 conference, Mosso met Albert "Skip" Rizzo, a psychologist (and

now director of medical VR) at the University of Southern California, who had been doing similar research with endoscopies. "He presented 10 cases," says Mosso. "I presented 200." Rizzo showed Mosso the expensive, state-of-the-art head-mounted displays he was using. "It was another world," says Mosso. But then Rizzo revealed the equipment with which he had begun – it was the exact same Spider-Man game.

"In this moment my life changed," says Mosso. "Skip saved me." Impressed by Mosso's work, Rizzo donated a headset to him and persuaded a colleague, Brenda Wiederhold of the Virtual Reality Medical Center in San Diego, to let Mosso use some virtual worlds she had developed specifically for [pain relief](#).

Mosso returned to Mexico with his new equipment and started to use VR in a much wider range of situations, from childbirth to recovery from heart surgery. It helped to relax patients across the board, but some of his most successful results were in minor day surgery, procedures such as removing lipomas, cysts and hernias, during which patients are awake but often sedated. He used a virtual scenario developed by Wiederhold called Enchanted Forest, in which users can explore rivers, lakes, trees and mountains. (The virtual world has to be relaxing, notes Mosso. A shoot-em-up game, no matter how distracting, might increase the risk of uncontrolled bleeding if the excitement raised patients' blood pressure.)

VR is now being studied by teams around the world to relieve pain in medical situations such as wound care and dentistry, as well as in chronic conditions such as phantom limb pain. But Mosso is still the only researcher to have published results on the use of VR during surgery. In one study of 140 patients he found that those using VR reported 24 per cent less pain and anxiety during surgery than a control group. He got similar results in a smaller randomised trial.

Offering patients VR also halved the amount of sedation they needed,

and in many cases avoided its use completely. That represents an important cost saving for the clinics in which Mosso works; sedative drugs such as fentanyl and midazolam are "very, very expensive", he says. He estimates that this reduced the cost of surgery by around 25 per cent, although he hasn't yet crunched the data to give an exact figure. Cutting drug doses should also reduce complication risks and recovery times for patients. Mosso is planning further trials to test this, but in general, he says, patients can go home an hour after surgery if they receive only local anaesthetic, whereas those who are sedated often need a whole day to recover.

"It cuts down on the cost, on the recovery time, and on the complications," says Wiederhold. "It's incredible. We still have not done that here in the US." Gregorio Obrador, dean of medicine at Panamerican University, is impressed too. At first, "I thought it was a little goofy," he admits. "I'm accustomed to giving pain medication." But after looking at the literature on VR and pain relief, "I'm convinced that it does work."

Overall, Mosso has now carried out more than 350 surgeries using VR, and says he'd love to see it used as a routine component of pain relief in operating rooms. Offered alongside medication, he thinks the technology could transform how patients are treated during a wide range of procedures. But he has a bigger vision. What if VR could be more than an alternative to sedation during hospital surgeries? Could it help him to bring surgery to patients where sedation isn't possible, where there are no hospitals at all?

Mosso's Jeep Cherokee is full to bursting. Tents, plastic food boxes, surgical equipment, medication, sanitary products and bags filled with clothes, sweaters and shoes are squeezed into every available space inside and tied precariously to the roof. On the back seat are Mosso's wife, Veronica – a gynaecologist – their youngest son, Olivier, and, to

keep the nine-year-old entertained, two baby iguanas recently captured from the forest near Acapulco, confined for the journey in a green net bag.

There's a long drive ahead. We are going to El Tepeyac, an isolated village hundreds of kilometres away in the mountains of Guerrero state. It's home to an indigenous Me'phaa community (often called Tlapaneco by outsiders), one of Mexico's poorest. "They have been forgotten," says Mosso. "They live with cold, on top of the mountain. They don't have hospitals, clinics, nothing."

As the high-rise blocks of Mexico City give way to sprawling shanty towns and then forested mountains, Mosso tells me about his father, Victorio. He was born close to El Tepeyac but left when he was 13, eventually becoming a teacher near Acapulco. He returned briefly to his childhood home after getting married, but never visited again until Mosso took him 40 years later. They found Victorio's youngest brother, Faustino. At first, neither brother recognised the other. "They said 'You look too old!'" recalls Mosso. "Then they were hugging, crying, a lot of emotions. It was the first time I saw my father cry."

Mosso was shocked by the poverty he saw, with dwellings that he felt could barely be described as houses. The villagers asked him to examine a patient, an old woman with a fever who was lying in a puddle on the floor (there had been a recent flood, and it was the only place close to the fire). She had pneumonia; Mosso told them there was nothing he could do. "She was my aunt," he says. "It was the last time I saw her. She died a few weeks later." He pauses, eyes fixed on the road. "That's why I go back. Because of my aunt."

In 2000, Mosso and Veronica began to travel to El Tepeyac every few months. They helped the villagers to build and stock a basic medical clinic, and carried out simple surgeries. But a few years ago their trips

stopped, due to a sharp rise in violence from the country's drug cartels. These organised criminal groups have been active across Mexico since the 1990s, producing heroin from poppies grown in the mountains here and exporting it to the US and Europe. Any violence was traditionally directed mostly at the authorities and each other, but since 2009 the cartels have increasingly targeted the general population with extortion and kidnappings.

The threat of violence is now routine for many Mexicans; the news here is filled with beheadings, mutilations and disappearances. On the freeway in the outskirts of Mexico City the day before, we had passed a group of four men, calmly crossing on foot between the busy traffic. One of them carried a young woman over his shoulder, either dead or unconscious, her dark hair spilling down past his hips. Mosso shrugged; for him the sight was nothing unusual. He works weekends at a hospital in this area and says he once had to order his surgical team to flee the [operating room](#) when a gunman entered the building, intent on killing their patient.

But the security situation is particularly bad in Guerrero, which is the country's most violent state, with one of the highest murder rates in the world.

According to a 2015 report by anthropologist Chris Kyle of the University of Alabama, Birmingham, illegal roadblocks, carjackings and kidnappings are routine here. The police have lost control, Kyle says, and there is "near complete impunity" for the perpetrators. In 2009, Mosso and Veronica reluctantly decided that it was too dangerous to travel. "We were coming to El Tepeyac four times a year," he says. "When the narc began, no more."

But he's desperate to see his family, and worried about the health of the villagers. So although the security situation hasn't improved, he is now

attempting the trip again. The obvious route from Mexico City is to take the highway via Guerrero's capital, Chilpanzingo, to Tlapa de Comonfort, the nearest town to El Tepeyac. But the road from Chilpanzingo to Tlapa – the main route for transporting opium out of the region – is "hell", Mosso says, with many shootings and kidnappings. Instead we take a roundabout route through the states of Morelos and Puebla. We travel by daylight and eat on the move, making just one brief stop, in a deserted lay-by, during the nine-hour drive.

His caution pays off; the only sign of trouble is three cars travelling in convoy – "When you see vehicles driving together like that, it's the narc," Mosso notes as we pass – and once we reach the steep streets of Tlapa, he visibly relaxes. In this largely indigenous area, self-organised community police groups have been relatively successful in limiting the violence of the cartels. From Tlapa, the road gets higher and rougher as the sun sets, eventually becoming a narrow, winding track of mud and stones.

We arrive to find El Tepeyac in darkness; the only power line was recently blown down by a storm. The villagers line up to meet us with flashlights, wide eyes and smiles looming out of the black. The welcome is a little awkward – many of them don't speak Spanish, and Mosso doesn't speak Me'phaa – until they direct us to a long, plastic table beneath a high shelter and feed us chicken soup and tortillas, freshly cooked over a fire, with steaming lemon tea.

The sun rises to reveal the centre of El Tepeyac as a handful of brightly painted concrete buildings surrounding a covered basketball court, where communal meals and functions are held. Around 150 people live here, their homes scattered across the mountainside, each with space for vegetables, chickens and cows, and a large rain butt for fresh water.

There's a breathtaking view over slopes forested with pine and

eucalyptus trees, with maize plants squeezed into every available space. (The terrain is also perfect for growing poppies, and although we don't see evidence of it in El Tepeyac, most communities in this region supplement their income in this way.) Mosso points out neighbouring villages – while most inhabitants of El Tepeyac are Me'phaa, the people in the next village belong to another indigenous group, the Mixteco, while the ones beyond that are Nahuatl, descendants of the Aztecs. There's no cell or TV signal here and these communities have limited contact with the outside world; instead, they communicate with each other by two-way radio and closed-circuit television, all in local dialects.

Straight after breakfast, Mosso visits another of his aunts. She's small and squat with missing teeth and lives with her son and daughter-in-law in a mud-brick house with a roof made of corrugated iron. She holds her nephew and weeps. Her husband, Victorio's brother, has passed away since Mosso's last visit. Of ten siblings, only one is still alive.

Then it's time for work. We walk down a muddy track to a single-storey building with two rooms, bare concrete floors and shelves stacked with pills. "We say it's a clinic," says Mosso, "but it's just a house." Would-be patients – some are from El Tepeyac, others have walked from neighbouring villages – wait in an open porch while Mosso and Veronica set up tables and chairs inside. This morning, the two doctors will each hold an open clinic.

Mosso's first patient of the day is a young mother. Her seven-month-old baby, Hector, has a flattened forehead and plaintive cry. Mosso diagnoses microcephaly: the baby's brain hasn't developed properly. The Zika virus is causing cases of microcephaly across Central and South America, but Mosso doesn't think that's the case here; the mosquitoes that carry the virus don't usually live at this altitude (2,300 metres), and the woman says she hasn't visited the coast.

She shows no emotion as he explains her baby's condition, then she thanks him and leaves.

He gets through around 20 patients during the morning. One anxious man has red tracks on his thighs from the claws of a tarantula that crawled into his trousers while he was working in the fields. He has since developed sensitive skin and back pain, which he fears is due to the spider's poison. Mosso prescribes antibiotics for cases of parasitosis and kidney infection, and diagnoses tooth decay in almost everyone; there is little education here about oral hygiene. Diabetes is common, too, as the villagers routinely consume sugary drinks instead of water. Mosso lectures one patient after another: "No Coca-Cola," he says. "Only one tortilla, not five."

One old man comes in with a hernia untreated for 20 years. The nearest doctor is in Tlapa, explains Mosso, an hour's drive away but a difficult journey without a car. The government does subsidise medical care for indigenous groups, he says, but even when they are able to travel they are sometimes discriminated against – put off from treatment – or they simply don't know who to see or what care is available. Mosso writes several personal referrals to colleagues in Tlapa, which he hopes will accelerate the villagers' access to the care they need. He also identifies a handful of cases suitable for surgery here in El Tepeyac. But there's a problem – the village is still without power.

After lunch at Mosso's niece's house, which turns out to be perched on the mountainside up a muddy track so steep it makes the Jeep's wheels spin, the lights come back on; the surgery can go ahead after all. The clinic floor is briskly swept as Mosso and Veronica put on scrubs and lay out scalpels. A nine-year-old girl named Joanna is on a bed by the window, screaming for her mother. Mosso is going to remove a lump of cartilage from behind her ear. She is wearing jeans and a T-shirt, and has bare, dirty feet. Through the window children are playing, adults sit in

chairs sharing home-brewed tequila, and the mountains stretch for miles. A fly crawls slowly over the paint-splattered floor.

Veronica fits the VR headset and the girl is immediately quiet. "I see fishes," she says. "I see water." Mosso has chosen for her an island world, with stone ruins and tropical fish beneath the sea. She remains still and calm until Mosso has finished stitching, then describes her experience. "I have never seen the sea," she says. "I liked it. I felt that the water was warm."

Then there are several lipomas to remove; these benign tumours are mostly harmless but if they cause pain, Mosso recommends surgery. He operates on a 54-year-old kindergarten teacher with two lipomas on her arm, and a man in his 20s who studied in Tlapa and has played video games before. The man is sceptical about the VR at first, but it was "better than I thought it would be", he allows after the surgery.

Next is 31-year-old Oliveria, her dark, curly hair tamed in silver butterfly clips. She has four children, works as a farmer and has walked from a village one-and-a-half hours to the south. She has a lipoma deep in her back, which hurts when she moves. It is a slightly trickier case than the others but the lump is likely to keep growing, so Mosso thinks it's best to remove it now.

Oliveria lies on her front in black jeans and a bra as Veronica fits the headset; she's watching the same undersea world as Joanna. Mosso injects local anaesthetic into the lump, makes a cut, and his white-gloved finger disappears to the knuckle. He feels around. "I'll have to open up the muscle," he concludes. He extends the cut and pulls open the flesh with metal brackets before reaching deeper than before. Eventually, he manages to pull the fatty ball free. Veronica holds it tight with tweezers as Mosso snips around: success. But the undersea world is suddenly replaced by an error message. The laptop wasn't plugged in, and the

battery is about to fail. A few seconds later, Mosso and Veronica realise that Oliveria has lost consciousness.

Everyone's moving. They turn the patient onto her back, Mosso rubbing her chest and shouting "Vamos a la casa!" while Veronica waves alcohol-soaked cotton wool under her nose. The pain triggered Oliveria's blood pressure to drop suddenly, explains Mosso, causing her to faint. He inserts an intravenous line with fluid to restore her [blood pressure](#). Shortly afterwards Oliveria moans, and bats away the cotton wool. "Breathe slowly," instructs Veronica. Mosso swats a fly from her face.

After a few minutes, they roll Oliveria onto her side to sew up the wound. Mosso doesn't have the facilities here to sedate her, or offer her any painkillers more powerful than the local anaesthetic, so he plugs in the laptop and switches the VR back on. Veronica keeps Oliveria talking as Mosso works. "What do you see?" she asks. "Fishes, water, stones," comes the reply. Then they help her to her feet and walk her to a bed in the next room. There's no stand or hook for the IV line so after some searching Oliveria ties it to an old floor lamp, which he balances on a table by the bed, next to Olivier's iguanas, happily munching lettuce on a plate.

"It looks easy, but we never know at what moment we can have a surprise," says Mosso when the crisis is over. "In a hospital I'm relaxed, because the monitor tells me the patient's heart rate, breathing, blood oxygen. There's an anaesthesiologist, scrub nurse, other surgeons. But here, we're far away from the hospital and my colleagues. With or without surprises, I'm worried. What if something happens here and I don't have solutions? Tlapa is far away."

Does he think it's worth the risks? "Yes," he says without hesitation. "They don't have the opportunity for surgery otherwise. And the risk is very low. In 350 patients, I just had one with this complication."

Half an hour later, Oliveria is ready to leave. "I didn't know I was going to have surgery today," she tells Mosso and Veronica. "Thank you."

Mosso gives her paracetamol and antibiotics, and instructs her to take a taxi home. She has asked to keep the lipoma so he hands her the twisted, blood-stained lobes in a small pot of alcohol. Her hands are shaking as she takes it.

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Next morning there's an impromptu farewell party on the basketball court. The village brass band accompanies a range of traditional Mexican dances, including one in which Mosso does a surprisingly athletic impression of an iguana.

He wants to leave early – today we will drive to Acapulco, where he plans to visit family (and release the real iguanas), before returning to Mexico City. Despite the circuitous route he has planned, it is unwise to be on the roads around Acapulco after nightfall. But there's another line of people at the clinic. Veronica hands out the clothes and supplies from the Jeep – donations from Olivier's school – while Mosso sees the patients. There's one more case for surgery: a boy with a haemangioma (a benign tumour of blood vessels) on his head. There isn't a strong medical need to remove it, but the boy is being bullied by his friends – "they say it's an insect," translates Mosso – and his mother is desperate.

Mosso agrees to the [surgery](#), but once that's done more patients arrive – they've walked an hour to see him. Mosso says no. It's already early afternoon, we have to go. We drive seven hours without stopping, the air ever warmer as we leave the mountains and climb down towards the sea. He's agitated, pushing 90 miles an hour along the long, straight coastal road, but we lose the race. The sun sets and we speed towards the city in darkness. Then cars coming the other way begin to flash their headlights, and shortly afterwards we're waved to a halt by a group of armed men in

military attire.

Mosso knows the drill. Quickly he opens his window, flips on the interior light and calls his son into the front. They're looking for enemies, he says. As long as they can see we're not hiding anything, they should let us through. Sure enough, the gunman looks inside and waves us on.

Once at his home in Acapulco, in a gated apartment complex, Mosso reflects on the trip. Apart from the fainting episode the patients all did well, and we travelled safely. "It was successful," he says. "I'm happy with the results."

He has collected data on all of the surgeries he carried out, and hopes that his experiences will encourage the use of VR to help [patients](#) in other under-resourced communities around the world. The cost of VR headsets has been prohibitive, but in the last year or two, the release of cheap devices such as the Samsung Gear VR (which costs less than £100) and even the Google Cardboard (£3), as well as the growing number of virtual worlds freely available online, have transformed access to the technology. "When we started, [virtual reality](#) was expensive, difficult to get and difficult to set up," says Mosso. "Today, everyone can use it." Although Mosso connected his headset to a laptop in El Tepeyac, he has previously shown that the technique works just as well running from a mobile phone, perfect for relieving [pain](#) in difficult locations. "There's no heavy equipment," he says. "It's very easy to use."

Meanwhile he is already making plans to return to El Tepeyac. During our trip, he met with a local government representative who wants him to visit not just that village but neighbouring indigenous communities too. That would take time and money that Mosso doesn't have, but he's trying to convince some of his colleagues in Mexico City to help, and hopes that soon he'll be able to return to Guerrero with a team of surgeons,

perhaps in spring 2017. He dreams of one day reaching even more remote communities – villages deep in the mountains that he has heard about but never visited, that have practically no contact with the outside world.

Mosso is one of the most upbeat people I have met. Tonight, though, his optimism is tempered. He says his overwhelming emotion on leaving El Tepeyac was anger. "I've seen some economic development," he says. "But my family are living in the same house, they are wearing the same clothes. All I gave is nothing. When I said goodbye I felt angry with myself, because I can't do anything for them."

He's painfully aware that it will take more than VR and donated sweaters to solve the problems of the people of El Tepeyac – and his country. But he's working to help them in the only way he knows.

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Citation: Virtually painless – how VR is making surgery simpler (2017, January 31) retrieved 6 May 2024 from <https://medicalxpress.com/news/2017-01-virtually-painless-vr-surgery-simpler.html>

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