Evaluating the Use of Stretchers in Two Mobile Refuge Alternatives

John R. Heberger and Jonisha P. Pollard

Abstract

In a mine emergency where refuge is necessary, miners may sustain injuries that will render them unable to walk or crawl. In this situation, a miner may have to rely on others for transportation into the mobile refuge alternative (RA) while on a stretcher. Since requirements for mine first-aid stations were developed before RAs, stretchers should be evaluated to determine whether they are usable in an RA and within the physical capabilities of miners in a refuge. The size of the RA airlock is a concern, as it has not been determined if current airlocks will accommodate a miner on a stretcher. This study evaluated the time required to move three types of stretchers into two commercially available RAs. The splint stretcher had the longest average time to move into each RA as compared to the backboard and soft stretcher. This increase was mostly due to the increased time requirements for getting the splint stretcher into the airlock. For all stretchers, it took approximately two to three times longer to enter the inflatable tent-type RA compared to the rigid steel RA. Mining companies should consider how well their current first-aid implements work with their RAs and manufacturers of inflatable RAs should maximize the size of the outer doors leading into the airlock to allow an easier entry for stretchers.

Keywords
Refuge alternative, stretcher, backboard, first aid

In a mine emergency that would necessitate taking refuge in a mobile refuge alternative (RA), it is possible that some miners may sustain injuries which would require them to rely on others for transportation into the RA while on a stretcher. Therefore, stretchers used in underground coal mine should be designed such that they are within the physical capabilities of the miners assisting the injured miner into the refuge. This article reviews the effectiveness of assisting a simulated injured miner strapped to three commonly used stretchers into two commercially available refuge alternatives by analyzing the time required to enter each RA.

Background & MSHA Standards

Section 2 of the Mine Improvement and New Emergency Response Act (MINER Act) of 2006 (Public Law 109-236) (MSHA, 2008) requires that underground coal operators include refuge alternatives in their emergency response plan. RA requirements are stipulated in the mandatory mine safety standards promulgated by MSHA. The Code of Federal Regulations (30 CFR 75.1713-7) requires that a stretcher and broken-back board must be included in every underground coal mine first-aid kit with each kit located no more than 500 ft away from the working faces. These provisions ensure that in the case that miners need to transport an injured miner out of the mine, they can do so in the most efficient manner possible.

Title 30 CFR 7.505(a)(3)(ii) requires that RAs include an airlock (purge area of a RA) that isolates the interior space from the mine atmosphere and that is designed to accommodate a stretcher without compromising its function (30 CFR 7.505). However, the standard does not specifically state that the airlock must be large enough to accommodate a stretcher while the outside door is closed and the inside door is open, which is a necessary condition in order to bring the injured miner into the refuge alternative through an airlock (MSHA, 2008). MSHA requires at least 15 sq. ft of floor space and 30 to 60 cubic ft of unrestricted volume in a RA (a range is given here because the recommended volume depends on the height of the mine) per person (30 CFR 7.505). The size of the airlock is of particular concern, as it has yet to be determined whether current RA designs will accommodate a miner on a stretcher.

Requirements for mine first-aid stations were developed before RAs were implemented as a safe location for miners to take shelter and wait to be rescued when escape is not possible. During this time, the primary goals of first-aid stations were to provide first aid, stabilize the spine and transport the miner out of the mine. With the addition of RAs in underground coal mines, there could be a need to transport an injured miner into the RA, which is a very different process from transporting them out of the mine. RA designs should be evaluated to ensure that they will allow miners to easily transport an injured miner on a stretcher

John R. Heberger is an epidemiologist in the Health Communications, Surveillance and Research Support Branch of the Office of Mine Safety and Health Research. He has an M.S. in Economics and an M.S. in Epidemiology from The State University of New York at Buffalo. He can be reached at jheberger@cdc.gov.

Jonisha P. Pollard, CPE, is the Musculoskeletal Disorders Prevention Team Leader in the Workplace Health Branch of the Office of Mine Safety and Health Research. She has an M.S. in Bioengineering from the University of Pittsburgh where she focused on human movement and rehabilitation biomechanics. Pollard can be reached at jpollard@cdc.gov.

into the airlock, complete the purging process, and move into the main living area.

Stretchers & Confined Spaces

Just as a miner carries another miner on a stretcher, paramedics experience similar situations when positioning an injured person on a stretcher in a confined or restricted space (Ferreira & Hignett, 2005). It is actually quite common that inadequate space in stairwells and narrow elevators in apartment buildings contribute to the delay of patient transport on a stretcher (Becker, et al., 1991; Lateef & Anatharaman, 2000; Morrison, et al., 2005). Underground coal miners in low seam mines may have an additional difficulty of needing to crawl on their knees to traverse the mine.

While the space limitations of a refuge alternative may not allow for the ideal spacing, at minimum, the RA should accommodate a miner lying on a regular-sized stretcher or backboard, and two assisting miners, without compromising the overall air quality in the airlock. This means that all three miners should be able to enter the RA airlock, close the entry door, purge the airlock, open the door to the main living area, and then move into the main living area.

Methods

Materials

Simulated Injured Miner

Three 35-lb fiberglass articulated joint male manikins (Figure 1) were used as the simulated injured miners (SIMs). The SIMs were 73 in. tall with a 38-in. chest, 29-in. waist and 38-in. hips. The SIMs were widest at the shoulders, measuring 21 in. wide. When lying flat on the ground, the heads were the highest, measuring 15 in. high. The SIMs were clothed in disposable coveralls. The SIMs were meant to represent the volume of a person, not the weight. The study participants were not actual underground coal miners and measuring the participants' strength by using 95th percentile male weighted manikins would not have yielded any valuable information. The outcome of interest was how well the SIMs fit into the RAs (which had very different airlock designs) when strapped to differing stretchers.

Stretchers

A full-length soft stretcher (Figure 1A) was utilized in this study. A stretcher is part of the standard first-aid kit as required by MSHA (30 CFR 75.1713-7). This stretcher was 80 in. long x 26 in. wide x 1/16-in. thick. It weighed 4 lb and could support up to 600 lb.

A full-length backboard (Figure 1B) was utilized in this study. It was 72 in. long x 16 in. wide x 1 in. thick. It could support up to 600 lb and weighed 16 lb. A full-length backboard is part of the standard mine first-aid kit as required by MSHA (30 CFR 75.1713-7).

Instead of having both a stretcher and backboard in the first-aid kit, MSHA allows the use of a splint stretcher (Figure 1C) to take the place of a stretcher and backboard (30 CFR 75.1713-7). The splint stretcher used weighed 30 lb, was 84 in. long x 23.5 in. wide x 7.5 in. high. It had a load capacity of 2,500 lb.

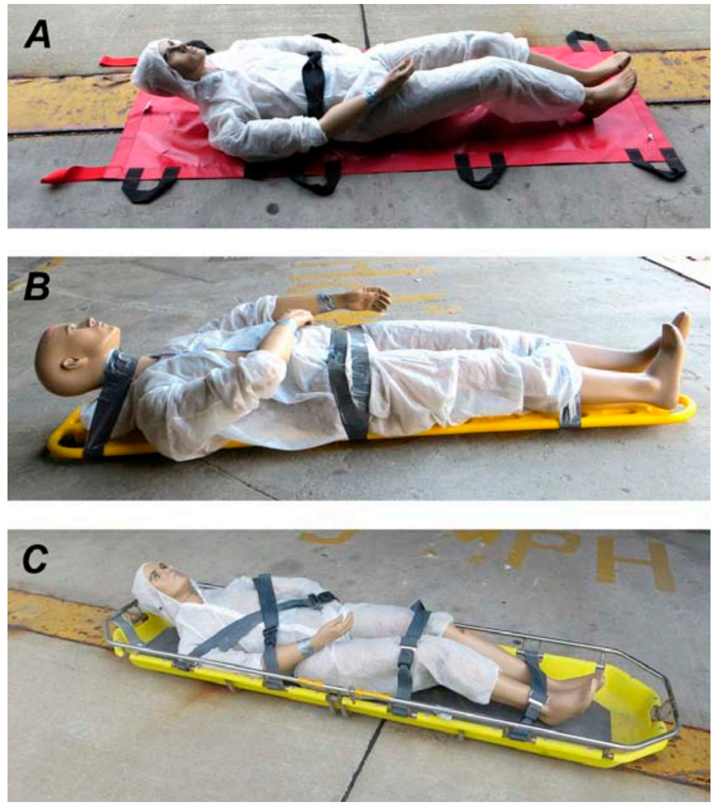

Figure 1: The simulated injured miners used were a 35-lb fiberglass articulated joint male manikin.
A) simulated injured miner on the soft stretcher;
B) on the full-length backboard secured with tape;
C) on the full length splint stretcher secured with the belts.

Refuge Alternatives

Two commercially available mobile refuge alternatives were used for this study: an inflatable tent-type RA and a rigid steel RA. The inflatable tent-type mobile RA was built by A.L. Lee Corp. It had a seven-person capacity airlock that was part of a 35-person capacity main living area. It was specifically designed for use in underground coal mines. Figure 2A (p. 300) shows that the airlock dimensions were 84 in. long x 40 in. wide x 30 in. high. The entry door was 24 in. wide x 25.5 in. high. The interior volume was 57 cubic ft. The entire airlock was surrounded by hard steel (a large steel box housed the uninflated main living area) on all sides except for the side which had the door to the main living area. This door was an inverted "U"-shaped flap that unzipped to allow access to the main area. This door was approximately 30 in. wide.

The rigid steel mobile RA was a hard-walled, eight-person capacity refuge alternative, with an eight-person capacity airlock, built by Jack Kennedy Metal Products and Buildings Inc. The interior airlock was 61.5 in. high x 89.5 in. long and had two different widths. At the widest, it was 52 in. wide while the narrowest part was 46 in. wide. The main front airlock door was 30.125 in. wide x 43.875 in. high. The interior door was 30.25 in. wide x 45.25 in. high. Interior volume was 153.5 cubic ft. Figure 2B (p. 300) provides a detailed drawing of the airlock.

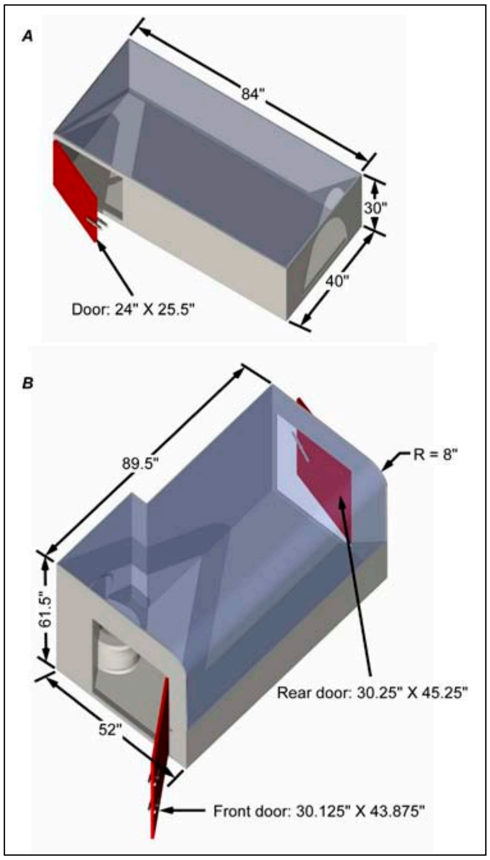

Figure 2: The dimensions of the A) inflatable tent-type and B) rigid steel mobile refuge alternative airlocks.

Participants

A convenience sample of 15 participants from the National Institute for Occupational Safety and Health (NIOSH), located at the Bruceton, PA, campus, responded to recruitment solicitations. Ten male participants had an average ± standard deviation of age, height and weight of 28 ± 5.5 years, 70 ± 2.5 in., and 205 ± 39.1 lb, respectively; as well as five female participants with an average ± standard deviation of age, height and weight of 29 ± 6.0 years, 64 ± 4.0 in. and 149 ± 28.0 lb, respectively.

The participants were generally in good health and physical condition. Males over age 45 or females over age 55 and any employee who reported pregnancy, cardiovascular disease, respiratory disease, musculoskeletal injuries, metabolic disease, claustrophobia, or who had more than one risk factor for cardiovascular disease (family history, current smoker, high blood pressure, obesity, sedentary lifestyle) were not allowed to participate. Before participating, each participant read and signed an informed consent form approved by the NIOSH Internal Review Board. All participants gave their consent to perform their task after being made aware of the study requirements and potential risks.

Procedures

A fully within-subjects experimental design was employed to investigate the effect of stretcher type and RA design on the time required to transport a SIM into an RA. The participants worked with the same researcher in teams of two and were instructed to move a SIM strapped to three types of stretchers from outside of the RA to the inside of the RA. Participants tested both an inflatable tent-type mobile RA and a rigid steel mobile RA with each type of stretcher in a fully randomized order. Stretchers were placed 4 ft away from and perpendicular to the RA entry door.

Participants (with the assistance of one researcher) first had to move the SIM from the outside of the RA and into the airlock. They then closed the outer door. Participants then were instructed to open the inner RA door and enter the main living area of the RA with the SIM. Once the SIM was inside the main living area, the participant then closed the inner door.

Times were measured with a stopwatch and recorded by another researcher. Time started when the participant signaled s/he was ready by touching the SIM. The first time recorded was after the team entered the airlock with the stretcher and closed the outer door. The second time recorded was after the team entered the main living area with the stretcher and closed the inner door behind them. Timings were recorded separately to determine whether one part of the process took significantly longer than the other.

The study ended when the participant successfully moved the SIM into the main living area of the RA and closed the door, after a 20-minute period had elapsed without being able to get the SIM inside the RA, or if the participant conceded that s/he was not able to move the SIM into the RA. The 20-minute period was selected as regulations dictate that purging of the airlock must be complete within 20 minutes of miners beginning to enter the RA [30 CFR 7.508(a)(1)].

Data Analysis Plan

Completion times for all stretchers and refuge alternative types were imported into statistical analysis software for further analysis (SPSS Statistics for Windows 19.0, IBM Corp., Armonk, NY). Data were analyzed using two-way repeated measures ANOVA and adjustments were used when the sphericity assumption was violated.

Results

All participants successfully moved the SIM into the main living area of the RA. No participant gave up or took longer than 20 minutes to maneuver the stretchers into the RAs. The results are presented in three sections. The first looks at the overall process of moving a stretcher from outside of the RA, through the airlock and into the main living area of the RA. The next two sections break the process down into two steps: 1) moving from outside the RA to inside of the airlock; 2) moving from the airlock to the main living area.

Moving Stretcher From Outside RA, Into Airlock & Into Main Living Area of RA

Mauchly's sphericity test indicates that the assumption of sphericity is met for stretcher type, and the interaction between RA and stretcher, so there was no need to correct the F-ratio. ANOVA summaries are shown in Table 1.

There was a significant main effect of RA type on total time to move from outside of the RA, into the purge area, and then into the main living area, $F(1,14) = 159.52$, $p < .001$, and a partial $\eta^2 = 0.92$, which is a large effect size. It took significantly more time to move into the inflatable RA ($\bar{x} = 50.6$ seconds) than it did the steel RA ($\bar{x} = 124.0$ seconds). There was also a significant main effect of type of stretcher used, $F(2,28) = 57.52$, $p < .001$ with a large effect size of Partial $\eta^2 = 0.80$. The splint stretcher took significantly longer time to move.

Most importantly, there was a significant interaction effect between the type of RA and the type of stretcher used, $F(2,28) = 39.24$, $p < .001$, partial $\eta^2 = 0.74$. This indicates that the type of stretcher used had different effects on the time to move into the RA depending on the type of RA. To break down interactions, contrasts were performed comparing the inflatable RA to the steel RA while the soft and backboard stretchers were compared with the baseline splint stretcher. These contrasts revealed significant interactions when comparing inflatable RAs to steel RAs both for backboards to splint stretchers, $F(1,14) = 63.85$, $p < .001$, partial $\eta^2 = 0.82$; and for comparing soft stretchers to splint stretchers, $F(1,14) = 52.55$, $p < .001$, partial $\eta^2 = 0.79$. Both effect sizes are large. Looking at the interaction graph (Figure 3), these effects reflect that the splint stretcher took significantly more time to enter the inflatable ($\bar{x} = 165.0$ seconds) than the steel RA ($\bar{x} = 56.4$ seconds), and the increase in time due to using a splint stretcher in an inflatable RA is significantly higher than using a backboard ($\bar{x} = 104.8$ seconds) or soft stretcher ($\bar{x} = 102.3$ seconds).

Source	Sum of Squares	df	Mean Square	F	p	Partial Eta Squared
Type of RA	121513.9	1	121513.9	159.5	0.000*	0.919
Error (RA)	10664.6	14	761.8			
Type of Stretcher	24841.9	2	12420.9	57.5	0.000*	0.804
Error (Stretcher)	6046.1	28	215.9			
RA by Stretcher	13890.5	2	6945.2	39.2	0.000*	0.737
Error (RA by Stretcher)	4955.5	28	177			
Contrasts Inflatable RA vs Steel RA						
Backboard vs Splint Stretcher	43524.3	1	43524.3	63.8	0.000*	0.820
Error (Backboard vs Splint Stretcher)	9543.7	14	681.7			
Soft vs. Splint Stretcher	39732.3	1	39732.3	52.5	0.000*	0.790
Error (Soft vs. Splint Stretcher)	10585.7	14	756.1			

Table 1: Total time to move from outside of RA, into airlock and inside main living area; ANOVA summary table. Statistical significance at $\alpha = 0.05$ is indicated by *.

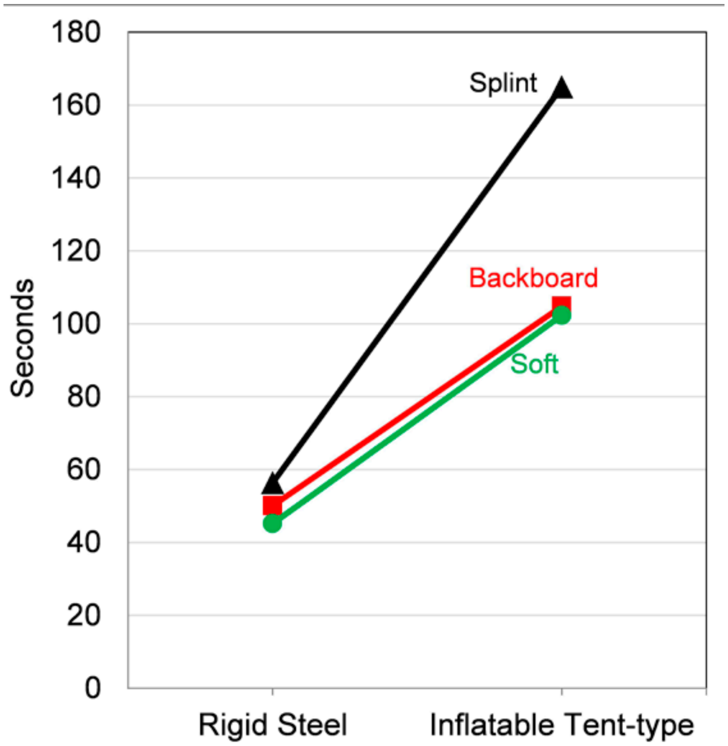

Figure 3: Average total time (rounded to whole seconds) to move the stretcher with SIM from outside of the RA into the main living area of each RA. The interaction graph shows that even though it always took longer to enter the inflatable RA, it took much longer to get the splint stretcher in the inflatable RA.

Moving Stretcher From Outside RA & Into Airlock

Mauchly's test indicated that the assumption of sphericity had been violated for the main effects of stretcher type, $\chi^2(2) = 16.12$, $p < .001$, and the interaction between RA and stretcher, $\chi^2(2) = 6.00$, $p = .05$. Therefore, degrees of freedom were corrected using Greenhouse-Geisser adjustment. ANOVA summaries are shown in Table 2 (p. 302).

There was a significant main effect of RA type on the time to enter the purge area, $F(1,14) = 96.44$, $p < .001$. Partial $\eta^2 = .873$ indicated a large effect size. It took significantly more time to enter the inflatable RA ($\bar{x} = 63.8$ seconds) than it did to enter the steel RA ($\bar{x} = 28.4$ seconds). There was also a significant main effect of the type of stretcher used on the time to enter the purge area, $F(1.17, 16.37) = 58.36$, $p < .001$ with the splint stretcher significantly taking the most time.

More importantly, there was a significant interaction effect between the type of RA and the type of stretcher used, $F(1.46,20.44) = 47.8$, $p < .001$, partial $\eta^2 = 0.77$. This indicates that stretcher type had different effects on the time to enter the purge area from the outside depending on which type of RA was used. To break down this interaction, contrasts were performed comparing the inflatable RA to the steel RA and all stretcher types were compared to the baseline splint stretcher. These contrasts revealed significant interactions when comparing inflatable RAs to steel RAs both for backboards to splint stretchers, $F(1,14) = 60.86$, $p < .001$, partial $\eta^2 = .81$, and for soft stretchers to splint stretchers, $F(1,14) = 51.76$, $p < .001$, partial $\eta^2 = .79$. Both have large effect sizes. Looking at the interaction graph (Figure 4, p. 302), these effects reflect that the splint stretcher took significantly longer to enter the inflatable RA airlock ($\bar{x} = 94.9$ seconds) than the steel RA airlock ($\bar{x} = 32.1$ seconds), and the increase in time due to using a splint stretcher in an inflatable RA is significantly higher than when using a backboard ($\bar{x} = 49.9$ seconds) or soft stretcher ($\bar{x} = 46.6$ seconds).

Source	Sum of Squares	df	Mean Square	F	p	Partial Eta Squared
RA type	28125.3	1	28125.3	96.4	0.000*	0.873
Error (RA)	4082.8	14	291.6			
Stretcher type	13703.6	1.2	11721.3	58.4	0.000*	0.807
Error (Stretcher)	3287.4	16.4	200.8			
RA by Stretcher	8496.3	1.5	5819.5	47.8	0.000*	0.773
Error (RA by Stretcher)	2488	20.4	121.7			
Contrasts: Inflatable RA vs Steel RA						
Backboard vs Splint Stretcher	23920.1	1	23920.1	60.9	0.000*	0.813
Error (Backboard vs Splint Stretcher)	5502.9	14	393.1			
Soft vs. Splint Stretcher	26966.4	1	26966.4	51.8	0.000*	0.787
Error (Soft vs. Splint Stretcher)	7293.6	14	521			

Table 2: Total time to move from outside of RA into airlock: ANOVA summary table. Statistical significance at $\alpha = 0.05$ is indicated by *.

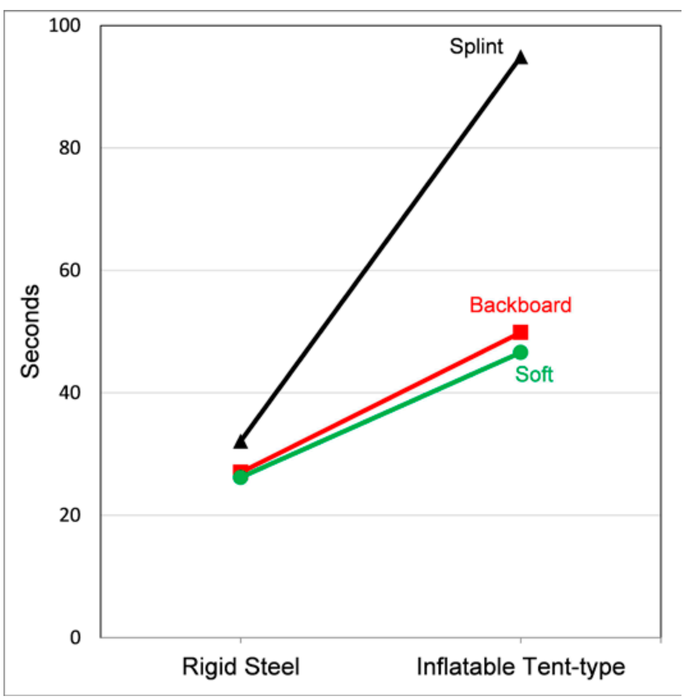

Figure 4: Average total time (rounded to whole seconds) to move the stretcher with SIM from outside of the RA into the RA airlock. The interaction graph shows that even though it always took longer to enter the inflatable RA, it took much longer to get the splint stretcher into the purge area of the inflatable RA.

Moving Stretcher From Airlock & Into Main Living Area of RA

Mauchly's sphericity test indicates that the assumption of sphericity is met, so there is no need to correct the F-ratio. ANOVA summaries are shown in Table 3. There was a significant main effect of type of RA on time to move from the purge area to the main living area, $F(1,14) = 127.39$, $p < .001$, partial $\eta^2 = .90$, which is a large effect size. It took significantly more time to move from the airlock to the main living area of the inflatable RA ($\bar{x} = 60.6$ seconds) than it did in the steel RA ($\bar{x} = 22.3$ seconds), as shown in Figure 5.

There was also a significant main effect of type of stretcher used on the time to move from the airlock to main area, $F(2,28) = 11.01$, $p < .001$. Contrasts revealed $F(1,14) = 12.86$, $p = .003$, partial $\eta^2 = .48$, that the splint stretcher ($\bar{x} = 47.6$ seconds) took significantly more time to move into the main living area of the RA than the backboard ($\bar{x} = 39.3$ seconds). The splint stretcher also took significantly more time to move into the main living area of the RA than the soft stretcher ($\bar{x} = 37.5$ seconds), $F(1,14) = 19.87$, $p = .001$, partial $\eta^2 = .59$.

There was not a significant interaction between type of RA and type of stretcher used (Figure 5), $F(2,28) = 2.91$, $p = .07$, partial $\eta^2 = .17$. This indicates that stretcher type did not have different effects on the time to move from the airlock to the main living area, depending on which type of RA was used.

Discussion

The splint stretcher always took the longest time to move into each RA. Moving the splint stretcher from outside of the RA and into the airlock was the driving force behind the increased time in the overall process of moving a stretcher from outside of the RA and into the main living area of the RA.

Overall, it does not matter what type of stretcher was tested—there is still an increased time difference when using the inflatable tent-type RA compared to the rigid steel RA. It took approximately two to three times longer to enter the inflatable tent-type RA with a stretcher compared to the rigid steel RA.

Splint Stretcher

The results showed that the splint stretcher was more difficult to move into the RA than the other stretchers. Since the individual characteristics of the stretchers were not tested, looking at the stretcher measurements can shed some light on why the splint stretcher took the longest time to move. Table 4 (p. 304) shows that the splint stretcher was the longest, highest and heaviest stretcher used in the study. The soft stretcher was widest and almost as long, but the flexibility of the soft stretcher allowed it to conform to the size of the SIM. It is likely that the rigidity as well as its length, width and height contributed to the difficulty in fitting the splint stretcher into the airlocks.

American Society for Testing and Materials (ASTM, 2007) standard for spinal immobilization devices does not give dimen-

Source	Sum of Squares	df	Mean Square	F	p	Partial Eta Squared
Type of RA	33100.8	1	33100.8	127.4	0.000*	0.901
Error (RA)	3637.8	14	259.8			
Type of Stretcher	1737.9	2	868.9	11	0.000*	0.440
Error (Stretcher)	2210.8	28	79			
RA by Stretcher	620.4	2	310.2	2.9	0.071	0.172
Error (RA by Stretcher)	2985	28	106.6			
Contrasts (Stretcher Type Only)						
Backboard vs Splint Stretcher	1041.7	1	1041.7	12.9	0.003*	0.479
Error (Backboard vs Splint Stretcher)	1133.8	14	81			
Soft vs. Splint Stretcher	1520.1	1	1520.1	19.9	0.001*	0.587
Error (Soft vs. Splint Stretcher)	1070.9	14	76.5			

Table 3: Total time to move from airlock and into main area of RA: ANOVA summary table. Statistical significance at $\alpha = 0.05$ is indicated by *.

sions, but does specify that a device intended for use with adult patients shall accommodate the 95th percentile adult American male. Centers for Disease Control and Prevention (CDC) reports the 95th percentile for height and weight in adult males of all races and ethnicities age 20 years and older as 74.3 in. and 270.3 lb, respectively (McDowell, et al., 2008). The European standards for heavy-duty stretchers specify that stretchers are to have a length of 1,950 mm (76.8 in.), width of 550 mm (21.7 in.), a maximum height of 300 mm (11.8 in.), and are to withstand a minimum load of 250 kilograms (551 lb) (CEN, 2012). Even though these standards are likely for wheeled stretchers used in ambulances, the splint stretcher is approximately 7 to 10 in. longer than the ASTM and European standards.

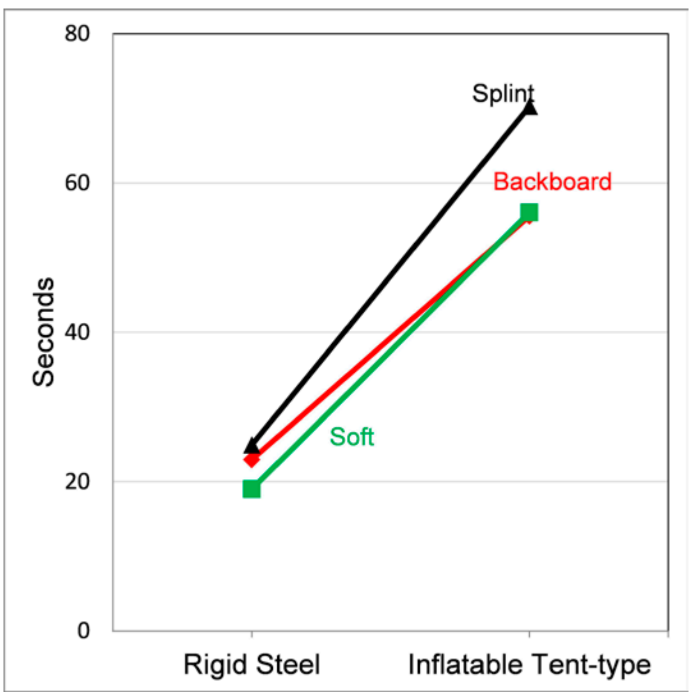

Figure 5: Average total time (in seconds) to move the stretcher with SIM from the airlock into the main living area. The interaction graph shows that the splint stretcher took the longest to move, and there is no significant interaction between RA type and stretcher type.

Airlock Design

It took participants a significantly longer time to move into the airlock of the inflatable RA than to move into the rigid steel airlock. The RAs used in the study had two different-sized airlocks as they were from two different RAs meant for two different types of mining. Therefore, a direct evaluation is not practical, but it is still useful to look at some features of the RAs that may have played a role in the increased time.

The lengths and widths of the RA airlocks were relatively similar (Table 5, p. 304). The main difference in the RAs was their height and therefore volume. The rigid steel RA had twice the height of the inflatable RA; participants had to stoop to enter the rigid steel (Figure 6. p. 305) but had to crawl to enter the inflatable RA (Figure 7. p. 305). This likely contributed to the increase in time because people can stoop-walk more quickly than they can crawl.

The emergency medicine field provides some reasonable guidelines for the dimensions of ambulance truck beds and doors, which must account for a stretcher/backboard in a confined space. The standard dimensions of the patient compartment in ambulances in the U.S., measured from the inside edge of the rear loading doors, must be at least 122 in. long, be at least 60 in. high, and have minimum volumes ranging from 275 to 325 cubic ft. The rear doors of an ambulance should have a minimum width of 44 in. and minimum height of 46 in. The patient compartment must also provide at least 10 in. of space from the edge of the stretcher to the rear loading doors (GSA, 2007). The European standards for loading doors have a width range of 900 mm to 1,050 mm (35.4 in. to 41.3 in.) and a height range of 900 mm to 1,500 mm (35.4 in. to 59.1 in.) depending on the type of ambulance (CEN, 2010). It should be noted that these dimensions also account for one or two emergency medical technicians as well as the patient, and also allow room to perform emergency procedures on the patient.

A feature worth noting is the door dimensions and door locations. Figure 2 (p. 300) shows the layout of the RAs. The rigid steel RA has the doors in line and parallel with each other. The stretchers were able to go straight into the airlocks, then straight into the main living area. The inflatable RA doors were perpendicular to each other. Participants had great difficulty getting the stretchers through the outer door while turning the stretcher 90 degrees in order to get it in line with the longest length of the

	Length (in)	Width (in)	Height (in)	Weight (lbs.)
SIM	72	21	15	35
Soft Stretcher	78.5	26	1/16	4
Splint Stretcher	84	23.5	7.5	30
Backboard	72	16	1	16
ASTM estimate	74.3	-	-	-
European standard	76.8	21.7	11.8	-

Table 4: SIM, stretcher and standards measurements.

airlock and parallel to the inner door to the main living area. The door width of the inflatable tent-type RA was also just enough to slide the splint stretcher through (with only a half-in. clearance), which may have also contributed to the difficulty in getting the splint stretcher into the airlock.

Standards and building codes for elevators also can provide guidance for dimensions of areas through which stretchers should traverse. The International Building Code states that an elevator car shall be of such a size and arrangement to accommodate an ambulance stretcher 24 in. x 84 in. (about the size of the splint stretcher) with not less than 5-in. radius corners (ICC, 2012). ANSI (2009) goes a step further and provides minimum dimensions for elevator cars depending on where the door is located. A door in the center of the elevator car must have a minimum opening of 42 in., and that car should have a minimum length of 80 in. and depth of 54 in. A door located off center of an elevator car must have at least: a door opening width of 36 in., length of 68 in. and depth of 54 in. Figure 8 (p. 306) shows examples of minimum elevator car dimensions as drawn in ANSI A117.1 standard (2009).

The emergency vehicle, building and elevator standards' measurements are generally larger than the dimensions of the RAs. Since underground coal RA airlocks will need to be purged of bad air before the miners can enter the main living area, it would not be beneficial to alter the dimensions of the airlock too much, as increasing the volume of the airlock would mean that the purging system would also likely need to be changed to effectively purge a higher volume of air. Changing the door location or type to allow for easier access into the airlock might be the best option.

Making the main door wider in the inflatable tent-type RA will likely make it much easier to get a stretcher inside, especially when having to turn the stretcher 90 degrees in order to fit into the airlock. Figure 9 (p. 306; NYC Buildings, 2011) shows a 76-in. by 24-in. stretcher fitting into elevators similar in size to the RAs; however, the door widths at 42 and 48 in. is considerably larger than the RA entry doors at 24 and 30.25 in. wide.

	Length (in)	Width (in)	Height (in)	Volume (ft^3)	Entry Door Width (in)	Entry Door Height (in)
Inflatable, Tent-type RA airlock	84	40	30	57	24	25.5
Rigid Steel RA airlock	89.5	46 - 52	61.5	153.5	30.25	45
U.S. ambulance patient compartments	Min 122		Min 60	Min 275-325	Min 44	Min 46
European ambulance standards					35.4 - 41.3	35.4 - 59.1
ANSI elevator center door location	Min 80	Min 54			Min 42	
ANSI elevator off-center door location	Min 68	Min 54			Min 36	
ANSI elevator any door location	Min 54	Min 80			Min 36	
ANSI elevator any door location	Min 60	Min 60			Min 36	

Table 5: Measurements of the RA airlocks, U.S. and European ambulance compartment standards, and ANSI elevator car standards.

Limitations

One limitation to note is that only two types of refuge alternative airlock designs from many designs were tested. Conclusions on rigid steel versus inflatable, tent type are not possible since RA features are confounded with RA type. For example, a steel RA airlock could have the same features and measurements of the inflatable type RA airlock used in this study. There could be rigid steel and tent-type RAs with similar airlock features and dimensions in which we would expect similar outcomes. Door size, door configuration, airlock dimensions, etc., must be considered.

Another limitation is that actual miners were not used. The study participants were researchers or technicians with little or no emergency medical training, and physical labor is not part of their daily tasks. It is also important to note that the SIM was just the average dimensions of a human, not an approximate weight. It would be much more difficult for anyone to move 50th percentile male weighted manikins, which would weigh about 175 lb. The purpose of the SIM was to simulate the size of a miner, and the goal of the study was not to measure strength of the participants. Future studies in this area may consider using miners as the participants and realistic height and weight manikins.

Figure 6: Moving the A) splint stretcher and B) full-length hard backboard stretcher into the rigid steel RA airlock.

Figure 7: Moving the A) splint stretcher and B) full-length hard backboard stretcher into the inflatable RA airlock.

Conclusions

In an emergency mine situation when escape is not possible, getting an injured miner into breathable air will be critical to his/her survival. Many types of stretchers and backboards are available for use. Mining companies should consider how well their current first-aid implements work with their refuge alternatives and ensure the feasibility of getting their stretchers/backboards into the airlock. It should also be noted that having a miner on a stretcher/backboard inside the airlock will decrease the number of miners able to fit in the airlock, thereby further increasing the time and purge air necessary to get all miners into a breathable air environment since the purge compartment needs to be purged for each group that enters. In these life-threatening situations, every second counts. Therefore, stretchers should be used which provide the best support for the injured miner while minimally increasing the time needed to get to breathable air inside of the refuge alternative. Moreover, manufacturers of inflatable refuge alternatives should maximize the size of the outer doors leading into the airlock to allow an easier entry for stretchers.

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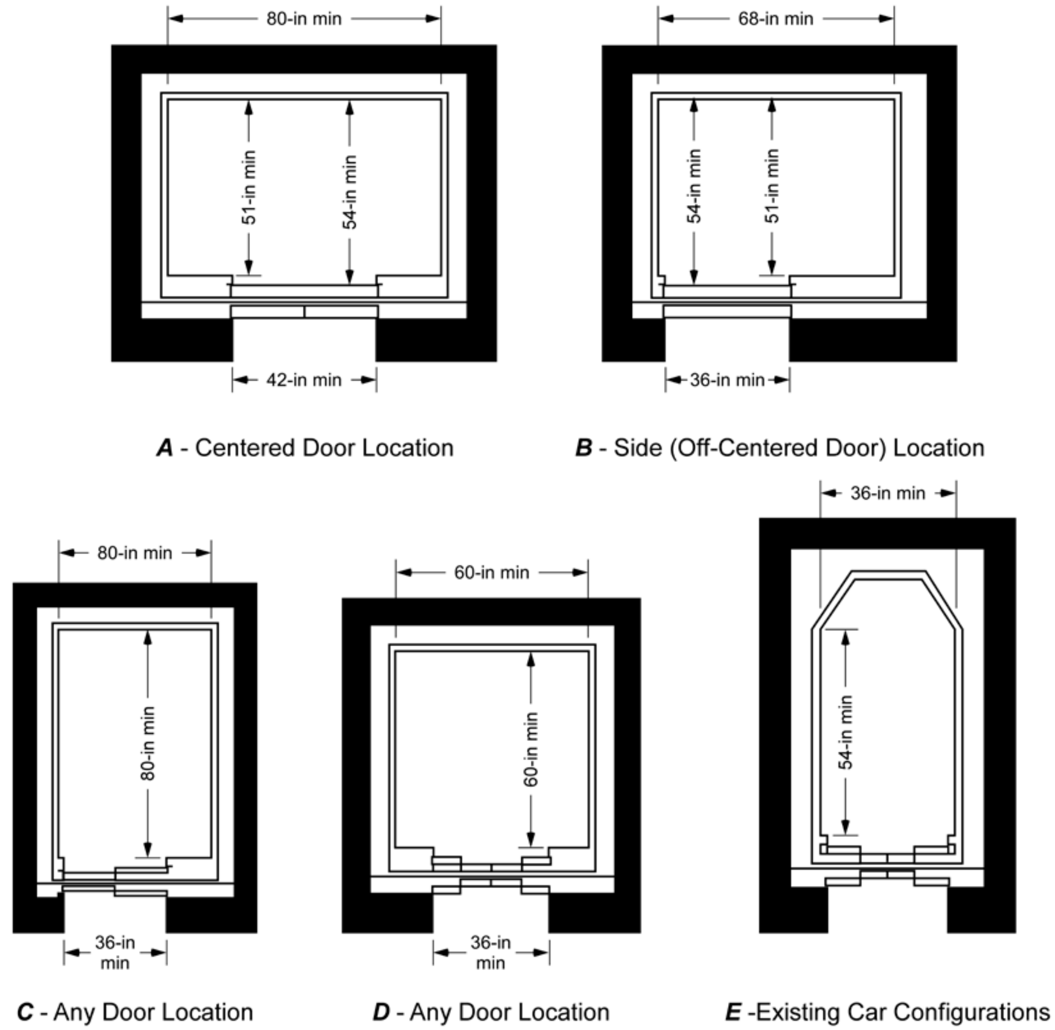

Figure 8: Examples of different configurations and interior elevator car dimensions (adapted from Fig 407.4.1 in ANSI, 2009).

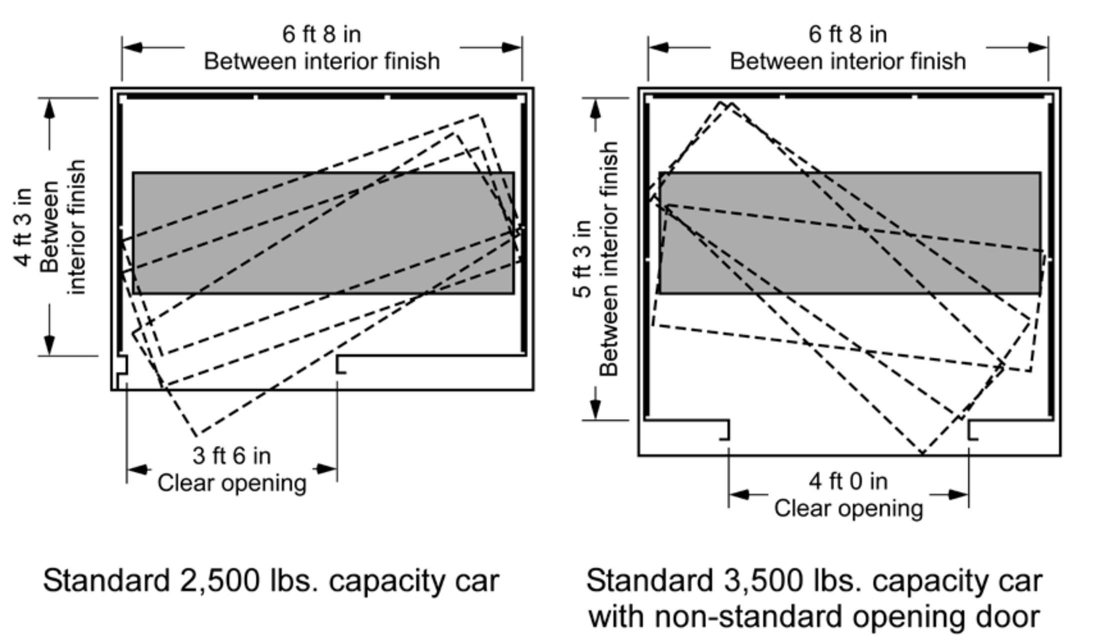

Figure 9: Elevator cars designed to accommodate stretchers. The dashed outline indicates how a 76 in. x 24 in. stretcher can maneuver into an elevator car and the grey area indicates stretcher fitment (adapted from Figure 1 in NYC Buildings Department, 2011).

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Phone (405) 744-5508
qingsheng.wang@okstate.edu

Editorial

This is my first year to serve as the editor for the *Journal of Safety, Health and Environmental Research* (JSHER). It is with my greatest pleasure to summarize three remarkable articles in the 2016 fall issue.

The first article, "Evaluating the Use of Stretchers in Two Mobile Refuge Alternatives," by Heberger and Pollard at National Institute for Occupational Safety and Health (NIOSH), focuses on the use of stretchers in mobile refuge alternatives. In a mine emergency, a miner may have to rely on others for transportation into the mobile refuge alternative (RA) while on a stretcher. This study evaluated the time required to move three types of stretchers into two commercially available RAs. The splint stretcher had the longest average time to move into each RA as compared to the backboard and soft stretcher. This increase was mostly due to the increased time requirements for getting the splint stretcher into the airlock. The authors found for all stretchers, it took approximately two to three times longer to enter the inflatable tent-type RA compared to the rigid steel RA. This study can benefit mining companies and manufacturers of inflatable RAs.

In the second article, "Perception of Occupational Risk by Volunteers and Paid Construction Workers," Moayed and Langsdale designed a cross-sectional study and an online survey to study occupational risk perception. The authors collected 476 responders from employees of a not-for-profit organization in the residential construction sector. A set of 2-way and 3-way contingency tables were created. The final results of Chi-square/Fisher Exact tests showed that volunteers' ranked their occupational risk lower than the paid workers, and that they had lower scores in general safety knowledge and safety climate evaluation compared to paid workers. Major confounding variables were gender, education, previous work-related injury and safety training. There were indications that volunteers and paid workers think differently in regard to their occupational risk and the safety climate, which can lead to disproportionate injury rates.

For the third article, "Forklift Operator Visibility Evaluation in a Manufacturing Environment," Shen and Marks evaluate the visibility of an equipment operator in a manufacturing environment. They conducted a series of experiments to simulate typical movements and actions of a forklift in a manufacturing plant. The test bed was assessed through laser scanning to identify areas not visible to the forklift operator. Point clouds of the test bed were generated and analyzed to identify nonvisibility areas for forklift operators. This research provided scientific evaluation data of operator visibility as well as a framework for measuring operator visibility in manufacturing work environments. Results of the research can be implemented to better understand causes of struck-by incidents as well as potentially mitigate visibility concerns in the manufacturing industry.

I hope that you enjoy these articles. As always, I look forward to hearing from you and welcome your submission of manuscripts to JSHER.

Sincerely,

Sam Wang, Ph.D., P.E., CSP
Managing Editor, JSHER

Acknowledgment of Reviewers

The *Journal of Safety, Health and Environmental Research* gratefully acknowledges the following individuals for their time and effort as manuscript reviewers from Sept. 1, 2015, to July 31, 2016. Their assistance in raising the standard of the manuscripts published is immense and greatly appreciated. Although the members of the Editorial Board (names are italicized) generally review more manuscripts than others (and provide much additional support), most reviews are handled by ad hoc reviewers, chosen for their unique expertise on the topics under consideration.

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