Equipment

The influence of tape type and of skin preparation on the force required to dislodge angiocatheters

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The study evaluated the effects of different techniques used to secure intravenous (iv) catheters. An angiocatheter attached to standard iv tubing was taped to human forearm using a standard taping method. A calibrated piezoelectric force transducer was attached to the iv tubing. The force applied along the longitudinal axis to pull out the taped catheter was measured and recorded on paper. Three tape types, Curity, Leukopor and Transpore, were evaluated alone, with benzoin skin pretreatment and with mastisol pretreatment. A randomized 3 × 3 block design with 20 replications per block was utilized, and a total of 180 pullout tests were performed on two adult volunteers. Without pretreatment, the forces required to dislodge catheters were (means ± SEM) 46 ± 2, 37 ± 2 and 38 ± 2 Newtons for Curity, Leukopor and Transpore tape, respectively. Corresponding values for mastisol pretreatment (64 ± 1, 64 ± 3 and 52 ± 3 Newtons) were greater ($P < 0.05$) for each tape compared with benzoin (54 ± 3, 53 ± 2 and 40 ± 2 Newtons) and no pretreatment. The most frequent failure mode for Transpore tape was by tape fracture, for Curity tape was by separation from the skin of tape and catheter as a single unit, and for Leukopor tape was by catheter separation while tape remained attached to skin ($P < 0.001$). The data suggest that the application of mastisol prior to taping iv catheters with Curity or Leukopor tape helps to minimize the risk of accidental dislodgement.

Cette étude vise à évaluer l'efficacité de différentes méthodes de fixation à la peau des canules iv. Un canule veineuse reliée a une tubulure ordinaire est fixée avec un ruban adhésif sur l'avant-bras selon une méthode standard. Un transducteur piézo-électrique calibré est attaché à la tubulure. La force appliquée sur l'axe longitudinal de la canule nécessaire pour l'enlever est mesurée et enregistrée sur papier. Trois type de rubans adhesifs Curity, Leukopor et Transpore sont évalués seuls et apres preparation de la peau au benjoin et au mastisol. Un schema randomisé de blocs 3 × 3 avec 20 répliques par bloc est utilisé, et un total de 180 tests d'extraction sont pratiqués sur deux volontaires adultes. Sans préparation de la peau, la force requise pour déloger la canule est (moyenne ± SEM) 46 ± 2, 37 ± 2 et 38 ± 2 newtons respectivement pour les rubans adhésifs Curity, Leukopor et Transpore. Les valeurs correspondantes pour la préparation au mastisol (64 ± 1, 64 ± 3 et 52 ± 3 newtons) sont plus élevées ($P < 0,05$) pour chacun des rubans adhésifs comparativement au benjoin (54 ± 3, 53 ± 2 et 40 ± 2 newtons) et à l'absence de préparation. Pour le ruban Transpore, la source la plus importante d'échec a été le bris du ruban, pour le ruban Curity la séparation du ruban et du cathétr en un seul bloc, et pour le ruban Leukopor par la séparation du cathéter alors que le ruban demeure collé à la peau ($P < 0,001$). Ces données suggèrent que l'application de Mastisol avant la fixation de la canule avec du ruban adhésif Leukopor ou Curity en diminue le risque de déplacement.

Key words
EQUIPMENT: catheters, intravenous.

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The secure adherence of devices such as intravenous (*iv*) angiocatheters, intra-arterial angiocatheters and endotracheal tubes to the skin is essential for perioperative patient management. Accidental dislodgement of one of

these devices due to inadequate fixation can be life-threatening and potentially devastating to the patient. One possible approach to prevent accidental dislodgement is to suture catheters or tubes into place. Another, is to utilize tapes with a higher degree of adhesiveness, or to pretreat the skin with liquid adhesives such as benzoin or mastisol in order to provide better adherence of the taped device to the skin. Since both benzoin and mastisol increase the adhesiveness of several brands of surgical wound closure tapes such as Steristrips,[1,2] it follows that the application of adhesive liquid resins to skin would increase the adherence of tape to the patient's skin, thereby increasing the force required to dislodge the device. The purpose of the study was to determine the force required to dislodge *iv* catheters that were secured to human skin with a standard taping method using three currently available tape types, and to determine whether the application of liquid adhesive agents could improve the adhesiveness. The study has clinical relevance because as anaesthetists, we are required to tape *iv* catheters to the patient's skin securely in order to minimize the risk of accidental dislodgement.

Methods

The study was approved by the Human Investigations Committee. Informed consent was obtained from two male volunteers (NP, DEH). The needle portion of a 14-gauge two-inch angiocatheter was removed, and the plastic hollow portion of the angiocatheter, attached to standard *iv* tubing, was taped to the forearm using a standardized technique. Three tape types currently in use at our hospital, Transpore plastic tape (Transpore surgical tape, 3M Health Care, St. Paul, MN), Curity cloth tape (Curity standard porous tape, Kendall Healthcare Products Co., Mansfield, MA) and Leukopor silk tape (Leukopor porous surgical tape, Beiersdorf Inc., Norwalk, CT) were evaluated alone, with tincture of benzoin (Ferndale Laboratories, Inc, Ferndale, Michigan) skin pretreatment and with mastisol (Ferndale Laboratories Inc) pretreatment. For the liquid adhesive skin pretreatments, a thin layer of either benzoin or mastisol was applied and allowed to dry prior to taping in accordance to the manufacturer's recommendations. Drying time was approximately one minute. Clean, dry skin in the less hairy anterior surface of the volunteer's forearm was used for all pullout tests. The taping method was chosen because it was easily reproducible in preliminary trials and it covered a relatively small surface area that would be tolerable for multiple pullout testing in humans. The taping method consisted of using a 2.5 by 10 cm tape with the sticky side facing away from the skin but towards the undersurface of the catheter, and creating an arrow-shaped loop along the longitudinal axis of the angiocatheter (Figure 1). This was reinforced with two 2.5 by 10 cm tapes applied perpendicularly to the catheter – the edge of the first transverse tape was at the end of the catheter hub and the second at the groove in the hub of the angiocatheter (Figures 2, 3). The tape was applied flat against the catheter surface and did not encircle the catheter. A calibrated piezoelectrical force transducer (50 kg range) was attached to the *iv* tubing such that a force applied along the longitudinal axis to pull out the taped catheter was measured and recorded on paper as described previously[3] (flat frequency response to 40 Hz). The pull out forces were generated by hand so as to simulate a clinical situation in which an angiocatheter is accidentally (or intentionally) pulled out with a large force of short duration. Preliminary tests indicated a satisfactory degree of reproducibility.[3] The experimental procedure is illustrated in Figure 4. A randomized 3 × 3 block design was utilized (tape × skin pretreatment), with each condition replicated 20 times, for a total of 180 pullout tests. The mechanism of dislodgement for each pull out test was evaluated and categorized as follows:

(A) the catheter pulled out while the tape remained on the skin;
(B) the tape fractured leading to catheter dislodgement;
(C) the entire tape and catheter unit separated from the skin.

Maximum pull out force for each tape-pretreatment combination was analyzed by ANOVA, followed by Tukey's test for multiple comparisons. Mechanism of dislodgement data was analyzed using chi square. Data are reported as mean values ± SEM. A P value less than 0.05 was considered significant.

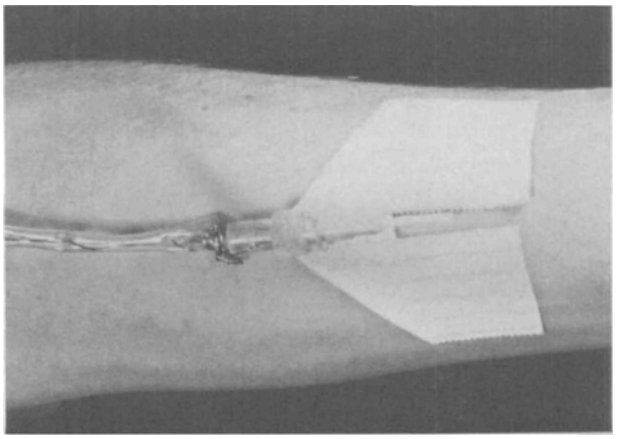
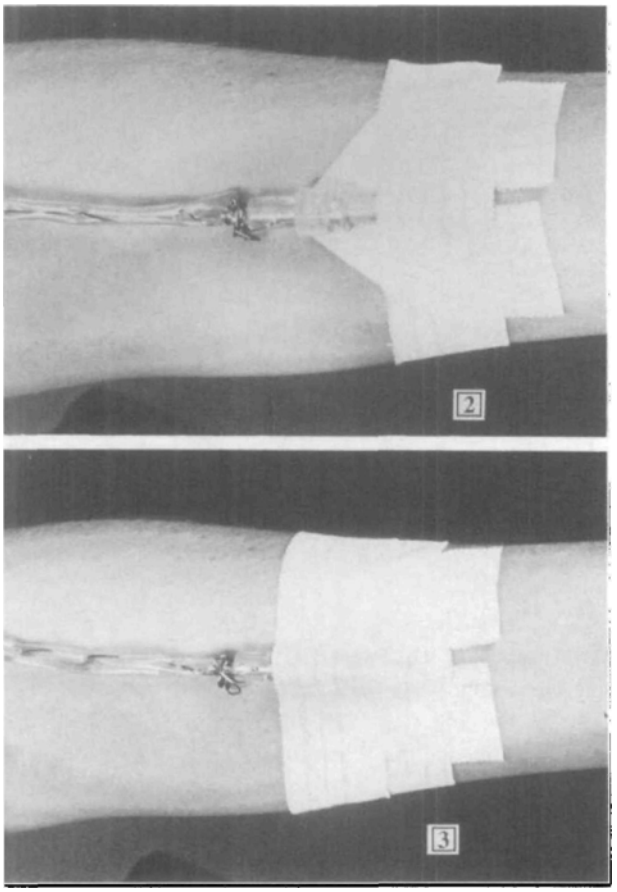


FIGURE 1 The plastic hollow portion of a 14-gauge 2-inch angiocatheter was initially secured to the anterior surface of the forearm using a one-inch by four-inch strip of tape (Curity tape in this example).



FIGURES 2 and 3 The initial strip of tape was reinforced by two one by four inch tapes that covered the angiocatheter hub and *iv* tubing connection. A Luer lock connection was used in all experiments to prevent separation of the catheter from the *iv* tubing connection.

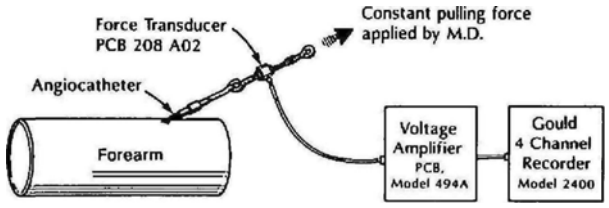


FIGURE 4 Illustration of the experimental procedure. Pullout force was applied in the longitudinal axis until dislodgement of the angiocatheter from the volunteer's forearm.

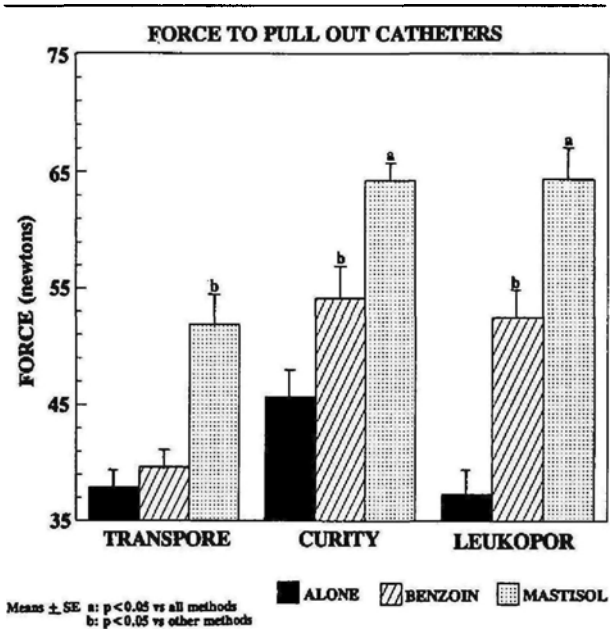


FIGURE 5 Maximum force (Newtons) to dislodge *iv* cathters using Transpore (plastic), Curity (cloth), and Leukopor (silk) tape alone, and with mastisol and benzoin skin pretreatment. Means ± SEM. (a) $P <$ 0.05 vs all methods, (b) $P < 0.05$ vs all other methods.

TABLE Mechanism of dislodgement for Transpore, Curity and Leukopor tape evaluated alone and with benzoin or mastisol pretreatment (data are number of occurrences; $n = 20$ for each tape-pretreatment combination).

		Alone	*Mastisol*	*Benzoin*
Curity	A	5	19	15
	B	0	0	0
	C	15	1	5
Transpore	A	6	0	8
	B	7	20	12
	C	7	0	0
Leukopor	A	10	20	20
	B	0	0	0
	C	10	0	0

Mechanism: (A) Catheter pulled out while the tape remained adhered to the skin; (B) Tape fractured leading to disconnection; (C) Catheter and tape separated from the skin as a unit.

Results

Pretreatment of skin with mastisol increased the required dislodgement force for all tapes studied compared with benzoin and no skin pretreatment (Figure 5). The combination of mastisol and Curity or Leukopor tape resisted pullout to the greatest extent (Figure 5). Analysis of mechanism of dislodgement data revealed that the most frequent failure mode for Transpore tape was by tape fracture, for Curity tape was by dislodgement of tape and catheter as a single unit, and for Leukopor tape was by catheter separation without tape fracture ($P < 0.001$, Chi Square, Table). Pretreatment of skin with mastisol and benzoin altered the method of dislodgement for Curity and Leukopor tape by reducing the frequency with which the tape separated from the skin ($P < 0.001$, Chi Square, Table). Retrospective analysis showed that there

were no differences in force and mechanism of dislodgement between the two volunteers.

Discussion

The practice of anaesthesia entails taping various devices to patients in order to minimize the risk of accidental dislodgement. In this study, the application of a thin layer of mastisol increased the force required to dislodge *iv* catheters secured by all tape types tested. In order of decreasing force to dislodge catheters were: Curity tape with mastisol, Leukopor tape with mastisol, Curity tape with benzoin, Leukopor tape with benzoin and Transpore tape with mastisol. Other authors have previously described the improved adhesive qualities of mastisol or benzoin. Mikhail *et al.* found that the application of a thin layer of both mastisol and benzoin increased the time of complete separation of steri strip surgical adhesives when small weights (150, 300 and 400 g) were suspended from the steri strips using a paper clip.[1] Compared with benzoin, the time for separation was greater with mastisol pretreatment.[1] Similarly, Moy and Quan found that the application of mastisol markedly increased the time to complete separation of seven different brands of surgical wound closure tape using a 225 g weight suspended from the tape.[2] The superiority of mastisol adhesiveness was also reported by Lesesne, who applied benzoin or mastisol to 300 patients undergoing various plastic surgical procedures prior to the application of surgical wound closure tape.[4] He found that mastisol-treated patients had a reduced incidence of surgical steri strip laxity due to loss of adhesiveness (10/150 patients, 7%) compared with benzoin treated patients (60/150 patients, 40%).[4]

The present study quantitatively described the force required to dislodge *iv* catheters. Two volunteers were used for the study in order to minimize the chance that one individual skin type would influence the results. It should be noted that only pullout force along the longitudinal axis was tested. Force applied in this direction was chosen because it was easily reproducible in a previous study,[3] and it was our clinical impression that the majority of *iv* catheter dislodgements and disconnections resulted from distal pulls along the longitudinal axis. However, it should be noted that forces applied in other planes may also result in dislodgement of the *iv* catheter (e.g., upward tugs). Other factors that may be important in securing the catheter and preventing accidental dislodgement include application of additional tape, use of armboards to restrict patient movement, restraining the patient, use of the arterial anchor bandage (Crystal Medical Products Inc., Libertyville, IL), suturing the catheter into place, removing hair and assuring a clean, dry skin surface prior to taping, and avoidance of catheter insertion near joints. Although not addressed in the study, it is the authors clinical impression that the adhesive qualities of tape, with or without liquid adhesives, deteriorate markedly when applied to skin covered with dense hair and to skin regions covered with perspiration, thus increasing the likelihood of accidental dislodgement. The amount of surface area covered by the tape using six different taping methods, as well as the separate adhesion of tape to the catheter-*iv* tubing connection hub has been shown to be of importance in resisting catheter pullout in s simulated patient forearm model.[3] It should be noted that the exact force encountered in the clinical setting resulting in catheter pullout is unknown. However, it would seem prudent to tape catheters to skin as securely as possible whenever there is risk of accidental dislodgement.

In summary, pretreatment of skin with mastisol enhanced the adhesive performance of all tapes tested. Benzoin improved the adhesive properties of Curity and Leukopor but not Transpore tape. The application of the liquid adhesives clearly altered the method of dislodgement by considerably reducing the frequency with which the tape separated from the skin. If the prevention of dislodgement of angiocatheters is clinically important, the data suggest that pretreatment of skin with mastisol using Curity or Leukopor cloth tapes resists pullout to the greatest extent. The results of the study also suggest that mastisol pretreatment may minimize the risk of accidental dislodgement of other devices that anaesthetists commonly tape into place, such as endotracheal tubes, nasogastric tubes and intra-arterial catheters.

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