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9. Venous Access

METHODS

Literature Search

Timeframe: Publications from 1992 until 2004, single publications from 1981 were considered.

Type of publications: original articles, case-control and cohort studies, randomised trials, meta-analyses, systematic reviews, case studies.

Key Words: catheterisation, catheter, Broviac, Hickman, ultrasound, replacement, complications, bacteraemia, parenteral nutrition, central venous catheter, central line, venous access, heparin, catheter handling, skin hygiene, dressing type, frequency of dressing change, intravenous infusions, catheter infections.

Language: English, French.

VENOUS ACCESS

Introduction

The use of central venous catheters (CVCs) to provide venous access has become increasingly common for the purpose of administration of different treatment regimens, intravenous nutrition and blood products, preventing at the same time trauma associated with repeated punctures. However, their insertion and usage may be associated with complications. Therefore, educated personnel should insert and look after the catheter, provide aseptic conditions in handling the catheter and maintain appropriate skin hygiene around the catheter.

The terminology used to identify various types of catheters differs and may be confusing. However, for the purpose of providing parenteral nutrition (PN), it is necessary to differentiate peripheral from central venous access, and among the central venous catheters (CVC) those non-tunnelled i.e. inserted either peripherally (PICC) or directly percutaneously, from tunnelled central catheters.

Intravascular Catheters for Parenteral Nutrition

Types of Catheters

Establishing a peripheral venous access is defined as placement of a needle or short catheter in a subcutaneous vein. As phlebitis of peripheral veins can be expected when the osmolality of i.v. solution exceeds 600 mOsm (1 (LOE 2+)), peripheral veins are only used for short-term venous access and for providing partial nutritional supplementation. Initiation of full PN requires the placement of a CVC. Central venous access is obtained by advancing a catheter into the superior or inferior vena cava or outside of the right atrium. A percutaneously placed CVC can be inserted directly through one of the deep veins e.g. subclavian, internal jugular, or femoral. Another option is a peripherally inserted central catheter (PICC), which uses a subcutaneous vein as the entry site to reach the central vein (2,3, LOE 3). For long-term continuous or frequent use, tunnelled catheters, such as Broviac or Hickman CVC's, are usually placed ((4) (LOE 2+), (5) (LOE 2+)). The extra vascular portion of these devices is tunnelled subcutaneously. A Dacron cuff is implanted subcutaneously, allowing for better fixation and, because of the distance between the insertion site and the entry into the vein, inhibits migration of micro organisms ((6) (LOE 1+); (7) (LOE 2+)). Totally implantable devices i.e. subcutaneous ports, are ideal for long-term but intermittent vascular access. Each port access requires needle sticking and, therefore, their value for PN is limited ((8) (LOE 2+)).

Recommendation

- Peripherally inserted central catheters (PICC's) and tunnelled central venous catheters (CVCs) should be used preferentially to provide central venous access in neonates and children receiving prolonged PN. **GOR C**

Catheter Material

Catheters made of stiffer material (polyvinylchloride, polypropylene, polyethylene) are easier to insert, but have been associated with more infectious and mechanical complications ((9) (LOE 2+)). Softer catheters (silicone and polyurethane) are less thrombogenic and less traumatic, and are, therefore, preferable for long-term use ((10) (LOE 2+); (11) (LOE 3)).

In adults, catheters coated with chlorhexidine/silver sulfadiazine and minocyline/rifampin, on both the external and internal surfaces, reduce the rate of catheter-related bloodstream infections ((12) (LOE 1+), (13) (LOE 1+)). In adults, in settings associated with high risk for infections (e.g. ICU patients), the use of these expensive devices might be cost-effective, and may justify the possible emergence of resistant bacterial strains ((14) (LOE 1+)).

Recommendation

- Silicone and polyurethane coated with hydromers are preferable materials for catheters used for long-term PN. **GOR C**

Insertion Sites

When a CVC is inserted into a deep vein, the choice of insertion site depends on the expected risk for thrombophlebitis, for mechanical complications and/or for catheter infection, which may all be specific for each insertion site.

The subclavian site is widely accepted as the preferred site of insertion, as it causes less patient discomfort, and in adult patients, carries the lowest risk of infection risk ((15) (LOE 2+), (16) (LOE 1−)).

In children, the subclavian site is also the most common site for insertion of tunnelled CVC's, although it has not been proven to carry less infection risk ((17) (LOE 1+); (18) (LOE 3)); (5) (LOE 2+)). Cannulation of the subclavian vein might be associated with dangerous complications such as pneumothorax and haemothorax. However, with adequate experience of the physician performing the procedure and sufficient sedation or general anaesthesia, the risk of mechanical complications in children at subclavian sites does not exceed the rate of complications at other insertion sites ((19) (LOE 3); (20) (LOE 3)). In contrast to adults, femoral catheters in children have not been shown to have a higher incidence of mechanical and infectious complications compared to jugular and subclavian sites ((21) (LOE 2+); (22) (LOE 3); (17) (LOE 1+); (23) (LOE 3); (24) (LOE 3)). However, femoral access is uncomfortable for the child while the consequences of potential inferior vena cava thrombosis may be severe. The insertion of a CVC is customarily followed by chest radiography for verification of the catheter's course and the position of its tip. In addition, ECG-monitoring may be helpful.

Statements and Recommendations

- In infants and children, in contrast to adults, femoral catheters do not show a higher incidence of mechanical and infectious complications in comparison with jugular and subclavian sites. **LOE 2**
- In children the risk of mechanical complications of subclavian venous access does not exceed the rate of complications with other insertion sites under appropriate conditions of insertion. **GOR C**

Positioning of the Catheter Tip

Cardiac tamponade is a rare but life threatening complication of CVC's ((25) (LOE 3), (26) (LOE 3)). There may be an increased risk of pericardial tamponade when the tip is placed within the heart outline as seen on chest x-ray ((27) (LOE 3), (28) (LOE 4)). It is, therefore, advisable that the CVC tip lies outside the pericardial sac and should be repositioned whenever possible ((27) (LOE 3); (29) (LOE 3)). The preferable position for the catheter tip on the chest x-ray is at least 0.5 cm outside the cardiac outline for the small infant, and 1.0 cm in larger infants ((28) (LOE 4)). For older children and adults, positioning above the carina, which can be used as an anatomic landmark, suggests that the catheter tip of the CVC placed in the superior vena cava is likely to be outside the pericardial sack ((30) (LOE 4)). The risk of perforation depends on the angle of the catheter and the vessel wall; therefore, the catheter should be parallel with the long axis of the vein ((31) (LOE 4)).

Statement and Recommendations

- The CVC tip should lie outside the pericardial sac to avoid the risk of pericardial tamponade. **GOR D**
- In small infants the catheter tip of a jugular or subclavian CVC should lie at least 0.5 cm outside the cardiac outline on a chest x-ray, while in older/larger infants that distance should be at least 1.0 cm. The catheter tip of a femoral catheter should lie above the renal veins. **GOR D**
- In older children, as in adults, positioning above the carina suggests that the catheter tip lying in the superior vena cava is likely to be outside the pericardial sack. **LOE 4**
- The risk of perforation increases with the acute angle of the catheter and the vessel wall. Therefore, the catheter should be parallel with the long axis of the vein. **GOR D**

Ultrasonic Guidance

The ultrasound-guided technique can significantly increase the precision and safety of CVC placement in children and newborns when the internal jugular vein is cannulated ((32) (LOE 3); (33) (LOE 3)).

Statement

- Ultrasound guidance may help reducing complications during internal jugular venous catheterization in children and in newborns. **LOE 3**

Methods of Insertion

Methods of insertion of CVCs, including tunnelled CVC's, are percutaneous placement and the surgical cut-down technique. The chance of permanent damage to the vein is increased when the cut-down method is used ((34) (LOE 2+)). The percutaneous insertion method is as effective as the surgical cut-down ((34) (LOE 2+), (35) (LOE 2+)).

Also, the diameter of the inserted catheter should be as small as possible to minimize the risk of scaring,

stricture, occlusion and distortion of the cannulated vein ((36) (LOE 3)).

In adults, administration of antibiotics before CVC insertion or the CVC flush with a combination of an antibiotic and heparin has been justified ((37) (LOE 1++)). In children, the use of vancomycin concurrent with catheter insertion was associated with decreased incidence of CVC blood stream infections ((38) (LOE 2+), (39) (LOE 2+)).

Statement and Recommendation

- Percutaneous, radiologically controlled, insertion method is equally effective as surgical cut-down, and carries less risk of damaging the vein. **LOE 2+**
- CVC placement should be done under strict aseptic environment, and preferably under general anesthesia and by an experienced team. **GOR D**

Umbilical Catheters

In neonates, umbilical vessels may be directly accessed in the first few days of life and, therefore, this route of central venous approach can regularly be used for PN. However, the risk of expected thrombotic complications limits the use of umbilical catheters to being a bridge procedure while awaiting placement of a long-term device ((40) (LOE 2+); (41) (LOE 2+); (42) (LOE 2+); (43) (LOE 2+)). Umbilical artery catheters placed above the diaphragm are associated with a lower incidence of vascular complications ((44) (LOE 1+)).

Statements

- In neonates, umbilical vessels can be used for PN.
- The risk of complications increases if umbilical artery catheters are being left in place for more than 5 days. **LOE 2++**
- The risk of complications increases if umbilical venous catheters are being left in place for more than 14 days. **LOE 1+**
- Umbilical artery catheters placed above the diaphragm are associated with a lower incidence of vascular complications. **LOE 1+**

Replacement Schedule

Routine replacement of CVC's and PICC's does not prevent catheter-related bloodstream infections ((45) (LOE 2+); (46) (LOE 1+); (47) (LOE 1+)). Functioning CVC's without evident complications should, therefore, be left in place as long as needed. A malfunctioning CVC can be replaced using a guide-wire insertion technique ((47) (LOE 1+)). This technique lowers the risk of mechanical complications associated with CVC replacement and may make chest radiography unnecessary in adult patients ((48) (LOE 2+)). Replacement over the guide-wire should, however, not be performed in the presence of bacteraemia or in patients suspected to have catheter related infection ((47) (LOE 1+)).

Recommendations

- CVC's and PICC's should not be replaced routinely. **GOR B**
- Malfunctioning non-tunelled CVCs can be replaced by using a guide-wire exchange technique, if there is no evidence of bacteraemia or catheter related infection. **GOR B**

Alternative Sites for CVC Placement

CVC complications following multiple catheterisations can lead to thrombosis and depletion of commonly used venous access sites. Alternative approaches in these children should be regarded as rescue accesses and include the transhepatic, translumbar, intercostal ((49) (LOE 3); (50) (LOE 3) (51) (LOE 3)), and the arteriovenous fistula (52). Preferences among the alternative sites depend on the experience of the physician performing the procedure and the condition of each individual patient.

Lines Designated Only to PN

In order to prevent catheter related infections, several recommendations have been suggested, including dedicating the CVC to PN only, i.e. not using it for blood sampling or for delivering other fluids or drugs ((53) (LOE 2++)). However, many of the patients who require PN are critically ill and have poor venous access, so the use of multiple lumen catheters allows additional access ports for the provision of compatible medications. Double and triple lumen catheters seem to be associated with an increased risk of bacteraemia compared to single lumen devices ((54) (LOE 2+); (55) (LOE 2++); (56) (LOE 2++)). They also seem to be more prone to the development of catheter-related sepsis, possibly because of more frequent catheter manipulations ((53) (LOE 2++); (57) (LOE 2+); (58) (LOE 1+)). The rate of catheter related sepsis has been reported to be as high as 10–20% compared to 0–5% associated with single lumen catheters ((53) (LOE 2++); (59) (LOE 1+); (58) (LOE 1+)).

In contrast, some adult studies showed that the use of multi lumen catheters for PN is safe and that they did not result in an increased incidence of catheter related sepsis ((60) (LOE 2+); (61) (LOE 2+); (62) (LOE 2++); (63) (LOE 1+); (64) (LOE 2++); (65) (LOE 1+)). It is

important to emphasize that in most of these studies either one port of the multiple lumen catheter was reserved only for PN, or the catheter was limited to administration of compatible medications and solutions while administration of blood products, withdrawal of blood and measurement of central venous pressure were prohibited. The authors concluded that PN can safely be given through multiple lumen catheters provided that these measures are strictly followed ((63) (LOE 1+), (64) (LOE 2++), (65) (LOE 1+)).

Statements and Recommendations

- Where possible a central venous line should be dedicated for the administration of PN. **GOR B**
- If a CVC is used to administer PN, use a catheter with the minimal number of ports or lumens essential for the management of the patient. **GOR B**
- If a multi lumen catheter is used to administer PN, designate one port exclusively for PN. Blood administration and central intravenous pressure monitoring from the designated line should be avoided. **GOR B** (from adult studies)
- If single lumen catheters are used, the risk of complications increases with blood sampling from the catheter. **GOR B** (from adult studies). However, to improve the quality of life of patients on long-term or home PN, blood sampling could be done from single lumen catheters, provided that the procedure is aseptic. **LOE 4**

Catheter Heparinisation

In children, central venous lines are the most frequent cause of venous thromboembolism and are responsible for over 80% of venous thromboembolism in newborns and 40% in other children ((66) (LOE 2++); (67) (LOE 2+)). Furthermore, CVC related thrombosis is, alongside sepsis, the most common clinically significant complication of PN ((68) (LOE 2+), (69) (LOE 2+)). Factors that have been associated with initiation and propagation of thrombosis include endothelial damage during catheter placement, blood vessel occlusion, low flow states, blood stasis, turbulent flow, blood hyperviscosity or hypercoagulability, patients' and infusates' characteristics and catheter composition ((70) (LOE 2++), (71) (LOE 1+)).

In an attempt to prolong the duration of catheter patency and to prevent venous thromboembolism as well as its potentially fatal complications, the use of heparin has been suggested ((72) (LOE 2+), (73) (LOE 2+)). Heparin is a glycosaminoglycan with anticoagulant effects mediated largely through its interaction with antithrombin III that markedly accelerates its ability to inactivate coagulation enzymes (thrombin, factor Xa and factor IXa) ((74) (LOE 2++)).

In providing PN, heparin could have the following potential benefits:

1. *anticoagulant action* – besides reducing fibronectin deposition, heparin makes the line hydrophobic, giving it a negative charge, both of which may influence the catheter thrombogenicity ((70) (LOE 2++); (75) (LOE 1+); (76) (LOE 1++));
2. *prevention of infection* – a thrombus might serve as a nidus for microbial colonization of intravascular catheters ((77) (LOE 1+); (78) (LOE 2++)). Heparin bonded catheters were reported to diminish bacterial adherence ((79) (LOE 2++)), as well as to lower the incidence of positive blood cultures, presumably related to the lower incidence of thrombosis ((70) (LOE 2++)) or to a reduced number of microorganisms attached to the surface of the catheter ((75) (LOE 1+));
3. *activation of lipoprotein lipase* - given in infusion, heparin also activates lipoprotein lipase and increases lipolysis and reesterification of infused triglycerides, but has no effect on lipid oxidation and net energy gain ((80) (LOE 1+); (81) (LOE 1+); (82) (LOE 2++); (83) (LOE 2++)).

There are certain possible complications related to the use of heparin in PN, notably bleeding, heparin induced thrombocytopenia, allergic reactions, osteoporosis, which all may result in serious long-term sequelae ((84) (LOE 2+); (85) (LOE 1++); (74) (LOE 2++); (86) (LOE 3)). In addition, neonates are unique in their sensitivity and resistance to heparin and in their higher propensity to develop intracranial haemorrhage ((87) (LOE 2−); (88) (LOE 2+)). Both low molecular weight heparin and heparin used as a catheter coating agent are associated with these complications, although the risk associated with low molecular weight heparin is reduced compared to unfractionated heparin ((85) (1++), (89) (2++), (90) (3)).

Another risk of adding heparin to PN solutions is the possibility of inducing incompatibility. Calcium and heparin can destabilize lipid emulsions leading to flocculation and separation of the lipid from the aqueous phase (91). However, this is unlikely if low heparin concentrations are used (0.5 to 1 U/ml) ((92) (LOE 2+)). Together with minimizing their contact time (having the delivery tube between the point of mixing lipid and amino acid solutions as short as possible), co-administration of vitamin preparations will further decrease this effect ((92) (LOE 2+)).

The current attitude towards prescribing heparin, therefore, differs with regard to whether to use it at all or not, and if yes, in what way (as a flush or in PN infusion), how often and how much. In practice, wide variations are observed in volumes of provided heparin ranging from 5 to 10 ml ((93) (LOE 2+), (94) (LOE 1+), (95) (LOE 1−)), concentration of heparin ranging from 10 U/ml to 200 U/ml ((93) (LOE 2+), (94) (LOE 1+), (69) (LOE 2+)) as well as in the frequency of

heparinisation that ranges from daily infusions ((96) (LOE 2++)) to flushes once or twice daily ((94) (LOE 1+); (97) (LOE 2+)) to once a week ((98) (LOE 2−)) or even once in three weeks ((99) (2++)). Boluses in children frequently contain 200 to 300 U of heparin, and for infants weighing less than 10 kg, a dose of 10 U/kg is frequently used ((89) (2++)). In a meta-analysis evaluating the benefit of heparin prophylaxis (3 U/ml in PN solution; 5000 U every 6 to 12 hours flush or 2500 U of low molecular weight heparin subcutaneously) in patients with CVC's, the risk of central venous thrombosis was significantly reduced. Although bacterial colonization was also decreased, no substantial difference in the rate of catheter related infection was observed ((100) (LOE 1+)). Of the 11 studies included in this meta-analysis only one was performed in the paediatric population. This randomised cross-over study showed that there was no significant difference in the incidence of blocked catheters or other complications between the group of paediatric patients whose CVC's were flushed twice daily with a heparin solution and the group with isotonic saline flushes applied once a week ((94) (LOE 1+)).

Another randomized double blind trial on paediatric patients demonstrated that the use of normal saline compared to heparinised infusion (saline + 1U of heparin/ml) did not significantly adversely affect patency of CVC's ((101) (LOE 1+)). The proportion of non patent catheters was smaller in the heparinised group but the difference was not statistically significant. However, both studies had a small sample size and thus not enough statistical power to draw definitive conclusions.

Shah et al performed a systematic review on the prophylactic use of heparin for prevention of complications related to peripherally placed percutaneous central venous catheters in neonates but not even one well designed randomized controlled trial was found. Therefore, the routine use of heparin for this purpose could not be recommended ((102) (LOE 1++)).

Later, Kamala et al performed a randomized, double-blind controlled study of heparin infusion (1 U/ml) for prevention of blockage of peripherally inserted central catheter in neonates and found no significant difference in the incidence of blocked catheters, catheter sepsis, hypertrigliceridaemia, hyperbilirubinaemia, coagulopathy or intraventricular haemorrhage between treated and untreated group ((103) (LOE 1−)). However, the study sample was again too small and with a high risk of bias.

Statements and Recommendation

- There is no proven benefit of heparin for the prevention of thrombotic occlusion of CVC's under regular use in children. Therefore its routine use is not recommended. **LOE 1−**
- With respect to CVC's not in regular use, in adults, flushing with 5 to 10 U/ml of heparinised saline once to twice weekly was useful in maintaining CVCs patency and is recommended. **GOR D**
- Routine use of heparin has not been shown to be useful in prevention of complications related to peripherally placed percutaneous CVCs in neonates. **LOE 1−**

Skin hygiene, Dressing Methods and Frequency of Dressing Changes

Skin Antisepsis and Hygiene

Extensive studies have been done to determine which antiseptic solution is the most effective way of removing micro organisms from the skin surface before catheter insertion and during catheter care. The best option appears to be 2% chlorhexidine, which was found to significantly reduce catheter related infections (CRI) ((104) (LOE 1+); (105) (LOE 2++)). In a comparison of 2% chlorhexidine to povidone-iodine and 70% alcohol, it was shown that the two latter solutions were associated with a fourfold higher incidence of CRI ((106) (LOE 1+)). However, when 0.5% chlorhexidine was applied and compared to 10% povidone-iodine no difference in prevention of catheter related bacteriemia could be demonstrated ((107) (LOE 1+)).

Recommendations

- Before insertion of an intravascular device and for post-insertion site care, a clean skin should be disinfected. Application of 2% chlorhexidine is preferred, rather then 10% povidone-iodine or 70% alcohol. **GOR A**
- Antiseptic solution should remain on the insertion site and air dry before catheter insertion or dressing application. **GOR D**
- Organic solvents (acetone, ether, etc.) should not to be applied on the skin before insertion of a catheter or during dressing changes. **GOR D**

Dressing Methods and Frequency of Dressing Changes

Apart from providing protection from external contamination, the purpose of the dressing is to secure the CVC and to prevent dislodgement and trauma. Traditionally it was common to dress the CVC site with dry gauze and tape. This method gave way to transparent polyurethane film dressings, defined as dressing composed of a thin

polyurethane membrane coated with a layer of acrylic adhesive. Potential advantages of these dressings include improved security of the catheter, visibility of the wound site, provision of an effective barrier to micro organisms and, therefore, less frequent need for dressing changing. However, there is a concern that the polyurethane dressings may increase the skin surface humidity, resulting in increased colonization of the micro organisms at the catheter insertion site ((108) (LOE 1+); (109) (LOE 1+); (110) (LOE 1+)), thereby increasing the risk of catheter related infections ((108) (LOE 1+), (111) (LOE 2+)).

Numerous studies have investigated the differences between dressing regimens (incidence of CVC-related infection, catheter security, dressing condition and ease of application, tolerance to dressing materials). The first meta-analysis that compared the effect of two different dressing types concluded that the risk of catheter tip infection, but not sepsis, was significantly increased with transparent CVC dressings compared to gauze and tape ((113) (LOE 1−)). However, according to the recent Cochrane Systematic Review by Gillies, et al., several factors could have biased the results of the above mentioned meta-analysis (114). This review failed to demonstrate any difference in the incidence of infectious complications between any dressing types compared (gauze and tape vs Opsite IV300, Opsite vs Opsite IV300, Tegaderm vs Opsite IV300, Tegaderm vs Opsite). As most of the included studies were performed on a small patient sample, they probably did not have a sufficient power to detect any differences between the groups. The authors, therefore, concluded that at this stage the choice of dressing for CVC can be based on patient preference, while the answer on ''What is the appropriate dressing to use for CVC'' requires further research ((114) (LOE 1++)).

Most of the studies mentioned have been done in adult populations, as there are very few studies involving children. A trial looking at the prevention of CVC infections in neonates concluded that the use of alcohol for cutaneous antiseptics with a subsequent placement of a chlorhexidine-impregnated dressing (Biopatch) over the insertion site of CVC (which should be left on for up to 7 days between dressing changes), provides protection against catheter tip colonisation. The rates of catheter related blood stream infections and blood stream infections without a source were, however, similar among treatment groups. A substantial risk of contact dermatitis at the dressing site may limit its use in low birth weight infants in the first 2 weeks of life ((115) (LOE 1+)).

Taylor et al, conducted a study on paediatric population with the aim of determining whether ''microbial growth increased significantly over time when occlusive dressings were used to cover CVC insertion sites''. They concluded that occlusive dressings, changed every 3 to 4 days using an aseptic technique, are safe and efficient and provide a barrier that prevents CVC exit site contamination with children's body fluids, food, and surgical wound drainage, and helps to anchor and stabilise the tubing ((116) (LOE 2−)). Although tunnelled central venous catheters with well-healed exit sites do not require any dressing to prevent dislodgement, it is useful to have them covered.

Concerning catheter submerging, according to Robbins et al, swimming does not increase the risk of catheter-related infections in children with tunnelled catheters ((117) (LOE 2−)).

The use of topical antibiotic ointments to clean the insertion sites at dressing changes is not recommended, as such ointments are associated with an increased frequency of fungal infections ((118) (LOE 1−)), antibiotic resistance ((119) (LOE 3)), and might adversely affect the integrity of polyurethane catheters ((120) (LOE 3), (120) (LOE 3)).

Recommendations

- Both, sterile gauze + tape and various transparent polyurethane film dressings can be used for the catheter site. **GOR A**
- If the catheter site is bleeding or oozing, a gauze dressing is preferable to a transparent, semi-permeable dressing. **LOE 4**
- The catheter-site dressing should be replaced when it becomes damp, loosened, or when inspection of the site is necessary. **GOR D**
- On short term CVC sites dressings should be replaced every 2 days for gauze dressings and at least every 7 days for transparent dressings, except in those paediatric patients in which the risk for dislodging the catheter outweighs the benefit of changing the dressing. **GOR B**
- Topical antimicrobial ointments should not be used routinely at the insertion site as they may promote fungal infection, antimicrobial resistance and damage the surface of the catheters. **GOR D**
- With tunneled catheters swimming is possible if the catheter is secured with water resistant dressing. **LOE 4**

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